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MANUAL OF PHYSICAL GEOGRAPHY

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MANUAL

OF

PHYSICAL GEOGRAPHY

BY

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PREFACE

The exercises in this "Manual" have, for the most part, grown out of the author's class-room experiences. There is presented a variety of exercises, some of them advanced in character, that will cover the topics capable of laboratory illustration usually presented in a course in physical geography. For such classes as cannot use the entire "Manual," the author suggests a selected list of exercises which are starred (*). Most of the exercises can be used in a different order from that given by omitting the references to other exercises.

Some of the exercises and their order of presentation may require explanation. Considerable attention is given to elementary principles of mathematical geography. Many students of this phase of the science seem to have a vocabulary rather than an understanding of it. For example, rather few students know precisely why it is colder in winter than in summer, or why the seasons change. The author would urge thorough drill in these elementary principles and in the elementary facts of insolation. Climate is treated early

in the course in order that a foundation may be laid for intelligent weather observations throughout the year. Especial attention is given to the cyclone, since it is the main climatic factor in the United States. If the teacher prefers to postpone the consideration of climate until later in the course, it can be done without inconvenience.

In presenting land forms due to normal erosion, the author has been most successful in grouping them according to their structure. Looked at in this way, the different types of mountains, for example, are produced by erosion acting upon different structures. Constructive imagination is brought out and a valuable discipline is secured. The author is aware that this plan leads into structural geology farther than many teachers care to go. The questions are therefore arranged so that the facts of structure can be omitted and the topographic facts studied by themselves. The topics of soils and harbors are introduced because they are geographic factors so important that every student should know of them.

It is the author's conviction that physical geography should lead up to, and should include a study of, the United States. To this end a series of exercises has been provided in Chapter XVIII to present important typical regions. Further reasons for these exercises

are that the preceding principles may be reviewed and that the student may gain facility in studying large areas. Few sciences offer better opportunities than physical geography for studying large units and grouping their various phenomena.

Wherever possible for the sake of economy, the same quadrangles have been used in different exercises. For those who wish to show the same features on different quadrangles, the United States Geological Survey has issued a useful pamphlet, "Topographic Maps of the United States showing Physiographic Types," which will be sent on application.

Most of the climatic tables have been taken from Hann's "Lehrbuch der Meteorologie," second edition, from "Climatology of the United States" by Alfred J. Henry, and from various tables published by the Smithsonian Institution. Many suggestions have been derived from "Climate" by Professor R. DeC. Ward and from the same author's "Handbook of Meteorology," from which the method in Exercise 27 is taken.

The thanks of the author are due to various Weather Bureau officials who have kindly furnished data; to Dr. J. A. Bonsteel, of the United States Soil Survey, who read the manuscript of the chapter on Soils; to Professor C. F. Marbut, of the University of Missouri, who has aided in many ways. The author is especially

indebted to Professor George D. Hubbard, of the Ohio State University, who read the manuscript and made many valuable suggestions.

FREDERICK V. EMERSON.

COLUMBIA, MISSOURI,
June, 1909.

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"Effective power in action is the true end of education."

— Eliot.

MANUAL OF PHYSICAL GEOGRAPHY

CHAPTER I

THE EARTH AS A PLANET

1. FORM OF THE EARTH

* PART I. — One of the best ways by which the form of the earth has been determined is the measurement of degrees of latitude on different parts of the earth's surface. If the earth were a perfect sphere, would the degrees of latitude be equal in all parts of the earth? If the earth were a spheroid as in Figure 1, what part of the spheroid would be a portion of a large circle? Why? Of a small circle? Why? In what part of Figure 1 would the latitude degrees be longest? Why? Shortest? Why?

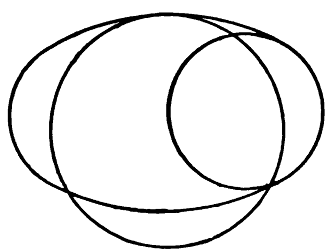


FIG. 1.

PART II. — Make a graph illustrating the length of latitude degrees as given in the table. A graph is a line drawn to illustrate a table of facts. Upon your

coördinate paper allow the heavy vertical lines to represent every ten degrees of latitude. Allow each lighter horizontal line to represent $\frac{1}{100}$ of a mile. Take the lowest corner to represent the lowest value in your table as a starting point. In this table this lowest value represents the length of the latitude degree at the equator. The length for 5° latitude is 68.71, and the point representing this value is at the intersection of the 5° line and the line representing 68.71 miles. Finish the location of points for each value, connect the points, and you have the graph.

LENGTH OF DEGREES OF LATITUDE AT VARIOUS LATITUDES

LATITUDE	MILES	LATITUDE	MILES	LATITUDE	MILES
0	68.704	35	68.935	65	69.281
5	68.710	40	68.993	70	69.324
10	68.725	45	69.054	75	69.360
15	68.751	50	69.115	80	69.386
20	68.786	55	69.175	85	69.402
25	68.829	60	69.230	90	69.407
30	68.879				

Is the graph a straight line? Does the graph indicate constant or changing values? Plot on same sheet a graph, assuming that the degrees are 68.70 miles long the world over. Is this a straight line? Why? Plot on the same sheet a graph, assuming that the latitude degrees increase $\frac{1}{100}$ of a mile for each 5° of latitude.

Is it a straight line? Why? Compare your three graphs as to straightness and direction. Does your graph of latitude degrees show increasing or decreasing values? Where is the greatest increase? Where the least? What does this show about the curvature of the earth? Where is the curvature greatest, at the equator or at 50°? At 20° or at 60°?

*2. THE EFFECTS OF THE INCLINATION OF THE EARTH'S AXIS

PART I. — To find the effect of the inclination of the earth's axis to the plane of the orbit, an apparatus

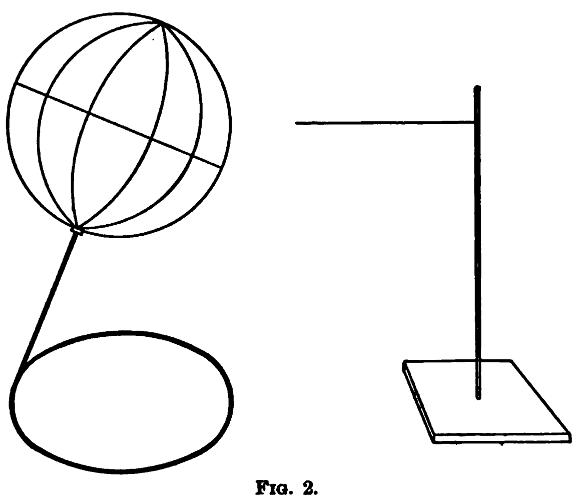


FIG. 2.

shown in Figure 2[1] will be useful. The horizontal wire represents the rays of the sun. First keeping the

[1] See Appendix.

axis vertical and parallel to its first position, move the earth in a circle, also moving the wire. Does the wire always point to the same latitude on the globe? How much of the earth is illuminated? Pass a cord or rubber band around the globe, dividing the illuminated and non-illuminated portions. Placing the globe so that the wire points to the equator, move the earth in a circle. Are the hemispheres equally illuminated? Change the inclination of the axis to about 23½°. Move the globe in a circle as before. Do the rays point always to the same latitude? If not, through how great a range of latitude are the rays vertical? Are the hemispheres equally illuminated at all times? At any times? Change the inclination of the axis to 10°; 50°; 90°. Compare in all respects with your previous results.

PART II. — Move the globe in a circle, but do not keep the axis parallel to its first position. How do your results compare with those in Part I?

PART III. — Referring to Parts I and II, what area of the globe receives direct rays of the sun at some time of the year? How wide is this area? How much beyond the poles does the circle of illumination extend? (The circle of illumination divides the lighted from the dark parts of the earth.) What is the tropical zone? What is its width? What determines its limits? What is the width of the polar zones? What determines their limits?

8. LENGTH OF DAY AND NIGHT

The reason for the varying length of day and night is often not thoroughly understood. Do not leave the topic until you can *demonstrate* it.

Take a globe and apparatus as in Exercise 2. How much of the earth is illuminated? Can it ever be more? Less? The boundary of the illuminated part is called the *circle of illumination*. Is it a *great* circle (*i.e.* does it always bisect the earth)? Place the globe in its position at equinox. Does the circle of illumination bisect the equator? The other parallels? What, therefore, is the length of day and night over the globe? Place the globe in the position of the June solstice. Is the equator bisected by the circle of illumination? Is the Tropic of Cancer? The Tropic of Capricorn? Are days and nights equal at the equator? Why? At the Tropic of Capricorn? Why? At the Tropic of Cancer? Why? Are days and nights always equal at the equator? Why? When only are they equal at other places?

Taking a given point, say your home city or some other city, follow it through the illuminated and non-illuminated portions of the earth at the June solstice. Does it pass for the greater distance through the illuminated or non-illuminated portions? Follow the same study for the December solstice.

It will now be apparent that unequal length of day

and night is due to the unequal division of the northern and southern hemispheres by the circle of illumination. That is, when the days are long, these hemispheres pass through a smaller shadow than when the days are short. The principle can be well shown by the apparatus shown in Figure 3. Take a globe (a slated globe is preferable) and compass. With one leg of the compass on the equator and the compass opening equal to the radius of the globe, the circle described will pass through the poles. This circle will represent the circle of illumination with the sun at its center. What time of the year is represented? Moving the leg of the compass north or south of the equator in the same way as the sun's vertical rays move, the circle of illumination can be shown for various positions of the sun. With this in mind demonstrate the following problems: —

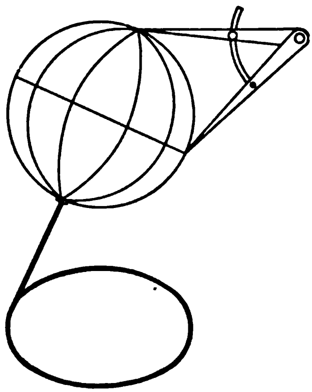


FIG. 3.

When the vertical rays are 5° north of the equator, what is the location of the circle of illumination near the North Pole? Near the South Pole? What is the position of the circle of illumination when the vertical rays are 20° north of the equator? When they are $23\frac{1}{2}°$ south of the equator?

From the following table plot graphs showing the length of day for 60° north and 60° south. (Use the length of day in minutes for plotting.) Why are the graphs pointed in opposite directions? Plot on another sheet of paper the graphs for 30° north and 30° south. (Use the same scale for each.) In which set of graphs is the greatest length of day shown? Why? The least? Why? Which graphs show the greatest range of length of day? Why?

TABLE SHOWING THE DURATION OF DIRECT SUNLIGHT ON THE FIFTEENTH OF EACH MONTH FOR LATITUDE: 60° NORTH, 60° SOUTH, 30° NORTH, AND 30° SOUTH

	60° North			60° South			30° North			30° South		
	hr.	m.	m.	hr.	m.	m.	hr.	m.	m.	hr.	m.	m.
January	6	19	379	17	41	1061	10	16	616	13	44	824
February	8	51	531	15	9	909	10	58	658	13	2	782
March	11	30	690	12	30	750	11	50	710	12	10	730
April	14	18	858	9	42	582	12	45	765	11	15	675
May	16	50	1010	7	10	430	13	31	811	10	29	629
June	18	26	1106	5	34	334	13	55	835	10	5	605
July	17	46	1066	6	14	374	13	46	826	10	14	614
August	15	27	927	8	33	513	13	7	787	10	53	653
September	12	43	763	11	17	677	12	14	734	11	46	706
October	10	0	600	14	0	840	11	21	681	12	39	759
November	7	17	437	16	43	1003	10	31	631	13	29	809
December	5	35	335	18	25	1105	10	5	605	13	55	835

4. LONGITUDE AND TIME

How long does it take the earth to make one *rotation?* Through how many degrees does the earth turn

to make one rotation? Through how many degrees does it rotate in an hour? In a minute? In a second? What is the difference in time between two places 45° of longitude apart? What is the difference in time between two places 65° apart? 90° apart?

If two places have a difference in time of 2 hours, how many degrees of longitude are they apart? How many if they have a difference in time of 3 hours 30 minutes? Of 6 hours 45 minutes? What is the difference in solar time between New York (74°) and San Francisco (122° 29′)? New York and Chicago (87° 36′)? Between New York and your own or nearest city?

5. TO ASCERTAIN THE NOON HOUR

From a south window hang a plumb line. Measure its shadow at different hours of the day and record their lengths. Plot these lengths. How do the shadows behave as noon is approached? As noon is receded from? Why is this so? What shadow, the longest or the shortest, represents noon? Why? (A perpendicular post will answer the same purpose as the plumb line.)

6. LONGITUDE

Arredono, Fla., and Nome, Alaska, Quadrangles. What are the latitudes of the Florida and Alaska maps? What difference in latitudes? What is the scale of the maps? What is the length (in miles) of five minutes of

longitude on the Florida map? What therefore is the length of a degree here? What is the length of a degree on the Alaska map? What is the reason for this change in length? What is the length of a degree of longitude at the poles? You will note that the Alaska map is narrower at the top than at the bottom. Why is this? Do the Florida maps show as much narrowing? Why? Draw to illustrate.

7. TO ASCERTAIN THE LOCAL LATITUDE

Using the same apparatus as in Exercise 5, find the length of the shadow. This should preferably be done at one of the equinoxes. Measure the shadow *BC* (Figure 4) at noon. The angle *ABC* represents the altitude of the sun. This angle can readily be obtained by trigonometry, or by construction as follows: Construct the right-angle triangle *ABC* to scale. Then the angle *ABC* can be measured with a protractor. The use of this angle will best be seen from a few problems. At the equator the sun at this time will be directly overhead. Angle *ABC* is 90°, and the complement of this is 0° or the latitude. In latitude 5° from the equator the angle *ABC* will be 95°. Applying the same reasoning, what is your latitude as determined from angle *ABC*? Compare this with your latitude as deter-

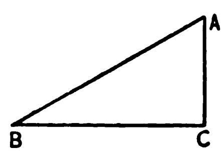


FIG. 4.

mined by more careful work. The local latitude can as easily be obtained at the solstices by adding or subtracting 23½°. If the angle *ABC* or the sun's altitude is 50° at the equinox, what is the latitude? If it is 50° at the June solstice, what is the latitude? What is the latitude if the sun's altitude is 50° at the December solstice?

8. REVOLUTION OF THE EARTH

* PART I. *Path of the Earth.* — From the following table plot a graph of the earth's distance from the sun.

TABLE SHOWING THE EARTH'S DISTANCE FROM THE SUN ON THE FIFTEENTH OF EACH MONTH (Derived for 1908)

MONTH	DISTANCE	MONTH	DISTANCE	MONTH	DISTANCE
January	9138×10^4	May	9394×10^4	September	9339×10^4
February	9177×10^4	June	9438×10^4	October	9259×10^4
March	9242×10^4	July	9442×10^4	November	9186×10^4
April	9324×10^4	August	9406×10^4	December	9141×10^4

When is the earth nearest (perihelion)? When farthest (aphelion)? Is the change from perihelion to aphelion sudden or abrupt? Does the graph show the earth's path to be a circle or an ellipse? If it were a circle, how would your graph appear? What is the average distance of the sun? (Find from your graph, not from computation.) What is the range of distances? (Find from your graph.) Preserve your graph. It will be needed later.

PART II. — From the following table plot the average daily velocities of the earth for the year.

TABLE SHOWING FOR EACH MONTH THE TOTAL DISTANCE IN MILES TRAVELED BY THE EARTH IN ITS ORBIT AND ITS AVERAGE DAILY VELOCITY (Calculated for 1908)

MONTH	MILES PER MONTH	AVERAGE DAILY VELOCITY	MONTH	MILES PER MONTH	AVERAGE DAILY VELOCITY
January	50,360,000	1,625,000	July	48,720,000	1,572,000
February	46,910,000	1,618,000	August	48,940,000	1,579,000
March	49,810,000	1,607,000	September	47,690,000	1,590,000
April	47,770,000	1,592,000	October	49,710,000	1,604,000
May	48,980,000	1,580,000	November	48,440,000	1,615,000
June	47,220,000	1,574,000	December	50,350,000	1,624,000

Are the velocities equal? How would your graph look if they were? When is the velocity greatest? When least? Compare your graph with that of Part I. Do their maxima and minima come at about the same time? Why?

How are the monthly velocity and distance from the sun related? When do the velocities change most suddenly? Why? At what parts of the year are the velocities least changing? Why? How does your graph show at a glance the rapid and the slow changes?

What is the total length of the earth's path? In what month is it longest? In what, shortest? How does its length from March to September, inclusive, compare with the rest of the year?

CHAPTER II

CLIMATE

TEMPERATURE

* 9. DIURNAL INSOLATION

How would you define insolation? What distinction between insolation and temperature?

APPARATUS: Take a board twelve inches long and two inches wide with the edge at one end sharpened. Nail the board to a support, say a piece of plank, with the sharp edge uppermost as in Figure 5. (Be sure to have the upright board at right angles to the support.) Turn the apparatus toward the sun, as in the figure, so as to throw a shadow of the upright. Measure the length of this shadow, *ac*, each hour of the day for as many days as possible. When does the upright not cast a shadow? Why? At this time is insolation greatest or least? Let several students take the readings and take the mean of their readings as the length of the shadow. Take temperature readings at the same times.

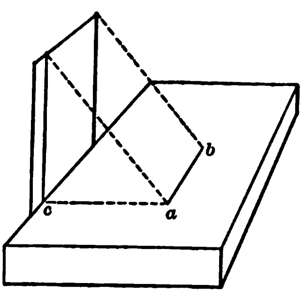


FIG. 5.

Plot the temperature readings and the lengths of shadow in two curves. When is the minimum and maximum of shadow and of insolation? Are the shadow lengths directly or inversely proportional to the insolations? Do the maximum and minimum insolations and temperatures coincide? Why?

Note. — With such crude apparatus, the insolation readings will not be accurate, but will bring out the general facts. It will probably be impossible to get the corresponding readings before and after noon to correspond. This experiment is best shown by the "Sun Board." See Appendix.

* 10. INSOLATION AT VARIOUS LATITUDES

The unit is the amount of insolation at the equator, with a vertical sun and average distance from the sun.

	80° N.	80° S.	60° N.	60° S.	40° N.	40° S.	20° N.	20° S.	0°
January	0.0	8.8	0.1	13.4	3.3	16.6	9.0	16.8	14.0
February	0.0	3.5	1.0	9.2	5.7	13.9	11.2	15.9	14.9
March	0.2	0.4	3.9	4.4	9.4	9.9	13.6	13.9	15.3
April	2.7	0.0	8.2	1.3	12.9	6.0	15.2	11.2	14.6
May	7.5	0.0	12.0	0.1	15.3	3.4	15.8	8.8	13.5
June	10.3	0.0	13.8	0.0	16.2	2.4	15.9	7.7	12.8
July	8.5	0.0	12.6	0.1	15.6	3.0	15.8	8.3	13.1
August	3.8	0.0	9.2	0.8	13.5	5.2	15.3	10.5	14.2
September	0.5	0.1	4.9	3.4	10.2	8.8	14.0	13.1	15.0
October	0.0	2.3	1.5	7.8	6.6	12.8	11.7	15.3	15.0
November	0.0	7.4	0.2	12.3	3.8	15.9	9.4	16.6	14.2
December	0.0	11.0	0.0	14.6	2.7	17.3	8.2	17.0	13.6
Year	33.5	33.5	67.4	67.4	115.2	115.2	155.1	155.1	170.2

The *total* insolation north and south of the equator is equal, while the *distribution* of the insolation is unequal. What latitudes have no insolation for part of the year? Why?

From the table, plot on a single sheet the insolations for 80° north, 80° south, 60° north, 40° north, 20° north, and the equator. Use continuous lines for insolation in north latitudes, and dotted lines for south latitudes. Allow ten small squares between each unit of insolation so as to allow for decimals.

What graphs are approximately parallel? What contrast in graphs for north and for south latitude? Why? What graph shows the highest insolation? What graph shows the highest average insolation? How do the graphs change in shape as you plot nearer the equator? Do they become the more or the less pointed? What does this change show as to the insolation?

How many maxima at the equator? When do they come? How many do the other graphs show? Explain their contrast in this respect with the graph for the equator. Are the maxima at the equator equal? Why? (See Exercise 8, Part I.) From the table determine how much greater is the total insolation at the equator than at 80°; than at 40°. Explain why. The insolation for a certain month is higher at 40° north and 40° south than for the equator. What months? Explain.

11. TABLE SHOWING THE LENGTH OF DAY IN MINUTES AT 60° NORTH LATITUDE, AND THE TEMPERATURE AT CHRISTIANIA, NORWAY, LATITUDE 59° 55′

January	379 m.	24.0°	July	1066 m.	62.6°
February	531 m.	23.9°	August	927 m.	60.6°
March	690 m.	34.5°	September	763 m.	52.7°
April	858 m.	39.9°	October	600 m.	41.9°
May	1010 m.	50.9°	November	437 m.	32.1°
June	1106 m.	59.9°	December	335 m.	25.5°

Plot the insolation from the table in Exercise 10, and the length of day and temperature from the above table. Are the graphs all parallel? Are any parallel? Why? (Give at least two reasons.) Why should the temperature lag behind the insolation? Do both the maximum and minimum temperatures lag behind the corresponding maximum and minimum of insolation? How does the maximum of insolation at 60° north compare with that at the equator? How does the minimum at 60° north compare with the minimum at 0°? Which, the maximum or the minimum at 60° north, shows the greatest contrast with the corresponding phase at the equator? How many hours long is the longest day at 60° north? The shortest day? Is the change of length of day gradual or abrupt? When is the most rapid change in length of day? The least rapid change? When is the most rapid change in insolation? The least rapid change?

*12. MAXIMA OF TEMPERATURE DUE TO INSOLATION. INTERIOR OF AFRICA, LAT. 8° 1′ N., LONG. 23.6° E.

January	73.4°	May	83.7°	September	77.7°
February	77.2°	June	81.5°	October	78.1°
March	83.8°	July	78.8°	November	75.7°
April	85.3°	August	75.7°	December	72.9°

Locate this part of Africa on a general map. Plot the temperatures. How many maxima? When do they occur? How many maxima of insolation on the equator? When do they occur? How many maxima at about 23° north and to the northward? (See Exercise 10.) About when do they occur? What is the cause of the maxima on the equator and the maximum of $23\frac{1}{2}°$? Why are the maxima later here than on the equator? How do the maxima of temperature and of insolation near the equator agree?

*13. CONTINENTAL AND MARINE AVERAGE ANNUAL TEMPERATURES. SAN FRANCISCO AND ST. LOUIS

	San Francisco	St. Louis		San Francisco	St. Louis
January	50	32	July	59	80
February	52	34	August	59	78
March	54	44	September	61	70
April	55	57	October	60	59
May	57	66	November	56	44
June	59	76	December	51	36

What is the latitude of these cities? Plot the temperatures. How much do they differ in range? Which has the warmer summer? The longer summer? The colder winter? What is the warmest month at San Francisco? At St. Louis? Which maximum comes sooner? How would you explain this? Which has the more changeable climate?

*14. AVERAGE HOURLY TEMPERATURES AT BISMARCK, N.D. (ALTITUDE 1681 FEET), AND PORTLAND, ORE. (ALTITUDE 157 FEET)

	Bismarck	Portland		Bismarck	Portland
1 A.M.	36.4	51.1	1 P.M.	45.0	51.0
2 A.M.	35.5	50.2	2 P.M.	46.8	52.7
3 A.M.	34.8	49.2	3 P.M.	48.1	54.5
4 A.M.	34.0	48.5	4 P.M.	48.9	55.8
5 A.M.	33.2	47.8	5 P.M.	49.0	56.9
6 A.M.	32.6	47.2	6 P.M.	48.3	57.5
7 A.M.	32.2	46.6	7 P.M.	46.7	57.6
8 A.M.	33.0	46.3	8 P.M.	44.7	57.2
9 A.M.	34.4	46.3	9 P.M.	42.3	56.1
10 A.M.	37.0	46.8	10 P.M.	40.2	54.9
11 A.M.	40.0	47.8	11 P.M.	38.7	53.4
N.	42.7	49.2	M.	37.4	52.2

What is the latitude of these places? What difference in altitude?

Plot the temperatures. What is the range of the two places? What difference in ranges? What is the

warmest hour at each place? What is the coldest? Does the daily graph show the same lag as the monthly graph? (Exercise 13) What is the explanation? Which climate is continental? Which marine? Give complete reasons for your answer.

15. TEMPERATURES ON THE EAST AND WEST SHORES OF OCEANS IN THE BELT OF WESTERLY WINDS

	Philadelphia	Opporto		Philadelphia	Opporto
January	32	49.2	August	74	69.0
February	34	51.2	September	68	66.7
March	40	54.5	October	57	60.2
April	51	57.0	November	45	53.1
May	62	62.0	December	36	48.5
June	72	65.4	Year	54	58.8
July	76	69.4			

What are the latitudes of Philadelphia and Opporto? What ocean separates them? How wide is it here? In what climatic zone is this region? What are the characteristics of this belt or zone? What prevalent wind directions? Plot their temperatures. Which graph shows characteristics of a marine climate? How? Which, a continental climate? How?

Since both places are situated near the ocean, how would you explain the fact that one has essentially a continental climate?

***16. TEMPERATURE AND ALTITUDE. TEMPERATURES AT SPRINGFIELD, ILL. (ALTITUDE 606 FEET), and BRECKENRIDGE, COL. (ALTITUDE 9524 FEET)**

	Springfield	Breckenridge		Springfield	Breckenridge
January	27	15	August	74	54
February	29	15	September	67	46
March	40	22	October	56	36
April	53	29	November	42	26
May	63	39	December	32	17
June	72	48	Year	52	
July	76	53			

Locate Springfield, Ill. What is its latitude? Breckenridge has about the same latitude. What difference in the heights of the two places? To how many miles is this equal? Plot the temperatures. How nearly parallel are the graphs? How do the average annual temperatures compare? The temperature ranges?

CHAPTER III

THE MOISTURE OF THE ATMOSPHERE

*17. WEIGHT OF WATER VAPOR IN A CUBIC FOOT OF AIR AT DIFFERENT TEMPERATURES (FAHRENHEIT). THE WEIGHT IS EXPRESSED IN TROY GRAINS PER CUBIC FOOT OF SATURATED AIR

−15°	0.28	20°	1.32	55°	4.84	90°	14.79
−10°	0.35	25°	1.61	60°	5.74	95°	17.12
−5°	0.45	30°	1.95	65°	6.78	100°	19.76
0°	0.56	35°	2.36	70°	7.98	105°	22.75
5°	0.70	40°	2.84	75°	9.35	110°	26.11
10°	0.87	45°	3.41	80°	10.93	115°	29.88
15°	1.07	50°	4.07	85°	12.73		

Plot the vapor weights and temperatures. (Use only the first figure of the decimal.) Do they increase uniformly as the temperature increases? If they did, what kind of a line would your graph be? At what temperatures is there the greatest increase in capacity? The least? From your graph determine approximately the capacity of the air of the room in which you are?

*18. OBSERVATIONS OF RELATIVE HUMIDITY

Read the temperature of your thermometer. (Dry-bulb reading.) Then wrap about the bulb of your ther-

mometer a bit of thin muslin moistened with water at the temperature of the air. Move the thermometer about or fan the bulb. Does the mercury rise or fall? Why? Why is it necessary to keep the air in motion around the bulb? When the mercury becomes stationary, take the reading. (Wet-bulb reading.)

Subtract the wet-bulb reading from the dry-bulb reading, and determine the relative humidity from the following table: —

Temp.	Difference between Dry- and Wet-bulb Thermometers																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
−10	48																	
−5	58	17																
0	67	35																
5	74	48	22															
10	78	57	35	14														
15	82	64	47	29	12													
20	85	70	56	41	27	13												
22	86	72	58	45	32	19	6											
24	87	74	61	48	36	24	11											
26	88	75	63	51	40	28	17	6										
28	88	77	65	54	43	33	22	11	1									
30	89	78	67	57	47	36	26	17	7									
32	90	79	69	59	50	40	31	21	12	3								
34	91	81	72	62	53	44	35	26	17	9								
36	91	82	73	66	56	47	38	30	22	14	6							
38	92	83	75	67	58	50	42	34	26	18	11	3						
40	92	84	76	68	60	53	45	38	30	22	16	8	1					
42	92	84	77	69	62	55	48	40	34	27	20	13	6					
44	92	85	78	70	63	57	50	43	37	30	24	17	11	5				
46	93	85	79	72	65	58	52	46	39	33	27	21	15	9	3			

Temp.	Difference between Dry- and Wet-bulb Thermometers																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
48	93	86	79	73	66	60	53	48	42	36	30	24	19	13	7	2		
50	93	87	80	74	67	61	55	50	44	38	33	27	22	16	11	6	1	
52	94	87	81	75	69	63	57	51	46	40	35	30	24	20	15	10	5	
54	94	88	82	76	70	64	59	53	48	43	38	32	28	23	18	13	8	4
56	94	88	82	77	71	65	60	55	50	44	40	35	30	25	21	16	12	8
58	94	89	83	78	72	67	61	56	51	46	42	37	33	28	24	19	15	11
60	94	89	84	78	73	68	63	58	53	48	44	39	34	30	26	22	18	14
62	95	89	84	79	74	69	64	59	54	50	45	41	37	32	28	24	20	16
64	95	90	85	79	74	70	65	60	56	51	47	43	38	34	30	27	23	19
66	95	90	85	80	75	71	66	61	57	53	49	45	40	36	32	29	25	22
68	95	90	85	81	76	71	67	63	58	54	50	46	42	38	34	31	27	24
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38	35	31	28
74	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40	36	33	30
76	95	91	87	82	78	74	70	66	63	59	55	52	48	45	41	38	35	31
78	96	91	87	83	79	75	71	67	63	60	56	53	50	46	43	39	36	33
80	96	92	87	83	79	75	72	68	64	61	57	54	51	47	44	41	38	35
82	96	92	88	84	80	76	72	69	65	62	58	55	52	48	45	42	39	36
84	96	92	88	84	80	77	73	69	66	63	59	56	53	49	46	44	41	38
86	96	92	88	84	81	77	73	70	67	63	60	57	54	51	48	45	42	39
88	96	92	88	85	81	77	74	71	67	64	61	58	55	52	49	46	43	40
90	96	92	88	85	81	78	75	71	68	65	62	59	56	53	50	47	44	41
95	96	93	89	86	82	79	76	72	69	66	63	60	58	55	52	49	47	44
100	97	93	90	86	83	80	77	74	71	68	65	62	59	57	54	51	49	47
105	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49

You will note that the left-hand column of figures denotes the air temperatures; the figures across the top of the table denote the differences between the dry-bulb and wet-bulb thermometers; the figures below these, in the vertical columns, denote the relative humidities at

the given temperatures, and for the given difference between the dry-bulb and wet-bulb thermometers.

For example, if the air temperature is 60° and the difference between the dry- and wet-bulb thermometer is 4°, the relative humidity is 78. Take for your observations the readings nearest to those given in the table. For example, if your reading is 61. 2° consider it as 61°.

Have readings taken each hour for several days by the class. Plot your readings as in Exercise 19.

*19. DIURNAL RELATIVE HUMIDITY AT COLUMBIA, MO., JULY 25, 1908. WINDS VERY LIGHT

	T.	R.H.	Sky	Wind
5 A.M.	74	82	Clear	S.E.
6 A.M.	76	76	Sunny	S.E.
7 A.M.	75	82	Cloudy	S.E.
8 A.M.	78	79	Sunny	S.E.
9 A.M.	79	75	Sunny	S.E.
10 A.M.	81	72	Cloudy	S.E.
11 A.M.	83	69	Sunny	S.E.
N.	83	69	Sunny	S.E.
1 P.M.	87	60	Sunny	S.E.
2 P.M.	87	60	Sunny	S.E.
3 P.M.	87	62	Sunny	S.E.
4 P.M.	86	63	Cloudy	S.E.
5 P.M.	86	65	Sunny	S.E.
6 P.M.	84	66	Sunny	S.E.
7 P.M.	82	69	Cloudy	S.E.
8 P.M.	81	72	Clear	S.E.
9 P.M.	80	79	Clear	S.E.
10 P.M.	78	83	Clear	S.E.

Plot the temperatures, placing the hours on the long side of the sheet and the temperatures on the narrow side. Plot the relative humidities on the same sheet, placing the graph below that for temperature. Are your graphs parallel? Explain the reasons for your answer. Which graph is most irrégular? What reasons can you give for this?

Plot also on the same sheet the absolute humidity as given in Exercise 17.

20. TEMPERATURE, ABSOLUTE HUMIDITY, AND RELATIVE HUMIDITY AT KEY WEST, FLA., AND SALT LAKE CITY, UTAH

(The absolute humidity is given in troy grains per cubic foot.)

	Key West			Salt Lake City				Key West			Salt Lake City		
	T.	A.H.	R.H.	T.	A.H.	R.H.		T.	A.H.	R.H.	T.	A.H.	R.H.
January	70	6.00	81	28	1.34	75	August	84	8.88	74	75	3.05	35
February	71	6.24	79	33	1.47	70	September	85	8.87	77	64	2.46	38
March	73	6.36	76	42	1.62	59	October	79	8.18	78	52	2.14	51
April	76	6.62	73	50	1.88	48	November	74	7.09	79	40	1.80	62
May	79	7.55	74	58	2.46	47	December	70	6.32	80	33	1.48	72
June	82	7.60	77	67	2.65	38	Year	77	7.47	77	52	2.24	52
July	84	8.75	74	76	2.97	34							

Plot, if possible, on the same sheet of paper, the temperatures, absolute humidities, and relative humidities for Key West and Salt Lake City. (If the paper is large enough, allow the first eight squares to represent

temperatures, the next eight to represent absolute humidities, and the next six to represent relative humidities.)

What graphs are most nearly parallel? What graphs have opposite directions? Which graphs show values that vary directly? Which, inversely? How would you explain these facts? How do your conclusions compare with those derived in Exercise 19?

From the temperatures, which climate would you infer has continental characteristics? What are these characteristics? Which marine? What characteristics? How would you describe the relative and absolute humidities in continental and marine climates as to amount, range, and distribution?

21. CLIMATE DURING AUGUST, 1896

	Boston	Philadelphia	St. Louis	Denver
T. 8 A.M.	69	72	72	60
T. 8 P.M.	70	77	82	79
Max. Temp.	78	85	88	85
Av. August	70	76	79	71
R.H. 8 A.M.	73	70	78	60
R.H. 8 P.M.	74	62	61	31

During August, 1896, in the Eastern and interior cities, there were thousands of cases of sunstroke and heat prostrations, while the cities of the Great Basin and Rocky Mountain region were fairly comfortable.

Analyze the table given above and determine what difference in climatic factors there were between Denver and the Eastern cities.

***22. EQUATORIAL RAINFALL. QUITO (In inches)**

January	3.2	April	6.6	July	1.4	October	4.4
February	6.4	May	5.1	August	1.8	November	6.2
March	4.4	June	2.5	September	1.8	December	2.8

Where is Quito? What is its latitude? Plot the rainfall. How does the graph compare with that for insolation? (Exercise 10.) How many maxima are there? How many minima? Do the maxima coincide with the maxima of insolation? (See Exercise 10.) Do they precede or follow them? What are the rainy months? The dry months? What is the annual rainfall? What percentage of this falls in the rainy seasons? Is the transition from rainy to drier seasons gradual or abrupt?

***23. TROPICAL RAINFALL. MEXICO (In inches)**

January	0.15	April	0.59	July	4.09	October	1.69
February	0.19	May	2.00	August	4.84	November	0.43
March	0.59	June	4.09	September	4.13	December	0.15

What is the latitude of Mexico? Plot its rainfall. When does the maximum come? When the minimum?

When is the maximum of insolation at about that latitude? (See Exercise 10.) What relation between the maxima of rainfall and of insolation? What is the reason for this? Does the maximum rainfall precede or follow the maximum insolation? Explain. What are the rainy months? The dry months?

24. MONSOONAL TYPE OF RAINFALL (In inches). CHERRAPUNJI, INDIA, LAT. 25° N.

January	0.8	April	30.9	July	130.8	October	13.7
February	2.8	May	51.4	August	79.6	November	2.2
March	8.8	June	115.9	September	56.1	December	0.2

What is a monsoon? What is its origin? Plot the rainfall. What is the total rainfall? When is the maximum? Does this maximum coincide with the maximum insolation? When is the minimum? What months are rainy? What dry?

CHAPTER IV

CYCLONES AND ANTICYCLONES

*25. GENERAL MAP STUDY OF A CYCLONE

WHERE is the center of the cyclone? What does the word *low* mean? What is the pressure at the center? How is pressure indicated? What does the word *isobar* mean? How does the pressure change as you go from the "low" outward? As you go *toward* the "low"? Roughly, what is the shape of the cyclone area? What is its approximate area?

In general, which way do the winds blow — to or from the center? Why? Do they blow straight into the center? What is the average wind velocity of ten places near, but not in, the center of the cyclone? Of ten places near the periphery of the cyclone? What is the general direction of winds in the easterly part of the cyclone? The westerly part?

How are temperatures shown? What is the meaning of the word *isotherm?* Do the isotherms go east and west across the cyclone?

How are states of sky shown: Rain? Snow? Thunderstorms? What information is given in the table that is not given in the weather map?

GENERAL STUDY OF AN ANTICYCLONE

Take up the same points in the study of a good anticyclone that you considered in the cyclone.

*26. CONSTRUCTION OF A WEATHER MAP

	Pressure	Temperature	Wind Direction	Wind Velocity	Sky
Escanaba, Mich.	28.9		N.	14	Snow
Green Bay, Wis.	28.9	30	N.W.	22	Cloudy
Marquette, Wis.	29.0		N.W.	20	Snow
La Crosse, Wis.	29.0		N.		Snow
Milwaukee, Wis.	29.0		N.W.	16	Cloudy
Grand Rapids, Mich.	29.0		S.W.	30	Snow
Alpena, Mich.	29.0		S.W.	14	Cloudy
Houghton, Mich.	29.1		N.	18	Snow
Dubuque, Ia.	29.1		N.W.	14	Snow
Chicago, Ill.	29.1		S.W.	24	Cloudy
Detroit, Mich.	29.1		S.W.	14	Cloudy
Saugeen, Can.	29.1	30	S.		Cloudy
White River, Can.	29.2	20			
Des Moines, Ia.	29.2		N.W.	12	Snow
Peoria, Ill.	29.2				
Sandusky, Ohio	29.2	40	S.W.		Cloudy
Buffalo, N.Y.	29.2		S.W.	24	Cloudy
Duluth, Minn.	29.3	20	N.W.		Cloudy
St. Paul, Minn.	29.3		N.W.	24	Cloudy
Keokuk, Ia.	29.3	20	S.W.	14	Cloudy
Pittsburg, Pa.	29.3	40	W.	14	Cloudy
Scranton, Pa.	29.3	40	N.W.	6	Cloudy
Oswego, N.Y.	29.3	30	S.	10	Rain
Rockcliffe, Can.	29.3	20	N.E.	0	Cloudy
Omaha, Neb.	29.4	20	N.W.	14	Clear
St. Louis, Mo.	29.4	30	W.	28	Cloudy

	Pressure	Temperature	Wind Direction	Wind Velocity	Sky
Cincinnati, Ohio	29.4	40	S.W.	16	
Elkins, W. Va.	29.4		W.	6	Rain
Richmond, Va.	29.4	50	S.W.	30	Cloudy
Atlantic City, N. J.	29.4		S.W.	20	Cloudy
Block Island, R.I.	29.4	50	S.	22	Rain
Albany, N.Y.	29.4		N.E.	6	Rain
Cape Henry, Va.	29.5		S.		Cloudy
Wytheville, Va.	29.5		W.	16	Cloudy
Lexington, Ky.	29.5		S.W.	28	Cloudy
Columbia, Mo.	29.5				
Moorehead, Minn.	29.6		N.	8	Clear
Devils Lake, N.D.	29.6	20	N.W.	4	Cloudy
Yankton, S.D.	29.6		N.W.		Cloudy
Kansas City, Mo.	29.6		W.	10	Clear
Springfield, Mo.	29.6	30	W.	12	Clear
Nashville, Tenn.	29.6	40	S.W.	14	Clear
Wilmington, N.C.	29.6		W.	14	Cloudy
Boston, Mass.	29.6	40	S.E.	6	Cloudy
Northfield, Vt.	29.6	30	S.	8	Cloudy
Charleston, S.C.	29.7		S.W.	12	Rain
Atlanta, Ga.	29.7		S.W.	14	Clear
Little Rock, Ark.	29.7		S.W.	8	Clear
Oklahoma, Ok.		30	W.		Cloudy
Dodge, Kan.	29.7		N.W.		Cloudy
Minnedosa, Can.	29.7		W.		Cloudy
Havre, Mont.	29.8		S.W.	26	Clear
Williston, N.D.	29.8		S.W.	Lt.	Clear
Pierre, S.D.	29.8		N.W.	18	Cloudy
Amarillo, Tex.	29.8		W.	24	Snow
Vicksburg, Miss.	29.8	40	S.W.	10	Cloudy
Montgomery, Ala.	29.8		W.	12	Cloudy
Tampa, Fla.	29.8	60	N.W.	Lt.	Rain
Key West, Fla.	29.9	70	S.	8	Cloudy
New Orleans, La.	29.9	40	N.W.	10	Cloudy

	Pressure	Temperature	Wind Direction	Wind Velocity	Sky
Abilene, Tex.	29.9	30	S.W.	6	Cloudy
Denver, Col.	29.9	30	N.W.	18	Cloudy
Miles City, Mont.	29.9		S.W.	Lt.	Clear
Kamloops, Can.	29.9	30	S.E.	Lt.	Clear
Cheyenne, Wyo.	30.0		N.W.	36	Cloudy
Roswell, N.M.	30.0		W.	Lt.	Clear
Galveston, Tex.	30.0		W.	8	Cloudy
Sante Fé, N.M.	30.1	20	N.E.	16	Clear
Helena, Mont.	30.1		W.	Lt.	Cloudy
Kalispel, Mont.	30.1		N.W.	Lt.	Clear
Victoria, Can.	30.1	40	E.	Lt.	Snow
Tacoma, Wash.	30.2	40	S.	8	Cloudy
Spokane, Wash.	30.2	30	N.E.	8	Cloudy
Lander, Wyo.	30.2	20	N.	Lt.	Clear
El Paso, Tex.	30.2		W.		Clear
Portland, Ore.	30.3	40	S.E.	Lt.	Cloudy
Baker City, Ore.	30.3	20	S.E.	Lt.	Clear
Grand Junction, Col.	30.3	20	N.	Lt.	Clear
Durango, Col.	30.3	0	N.	Lt.	Clear
Flagstaff, Ariz.	30.3	10	E.	Lt.	Clear
Winnemucca, Nev.		10	N.E.	Lt.	Clear
Independence, Cal.	30.3	30		10	Clear
San Francisco, Cal.	30.3	40	N.	Lt.	Clear
Roseburg, Ore.	30.4	40	S.	Lt.	Cloudy
Boisé, Id.	30.4		N.W.	Lt.	Cloudy
Salt Lake City, Utah	30.4		N.E.	0	Cloudy
Modena, Utah	30.4	0			
Sacramento, Cal.	30.4	30	N.W.	6	Clear
Red Bluff, Cal.	30.4	30	N.	Lt.	Clear

On a blank weather map (form *DD*), sketch in the isobars (continuous lines). What is the lowest pressure? Where is it? The highest pressure? Where is it?

Where is there a cyclone? What states does it cover? An anticyclone? What states covered? Where are the isobars close together? Where farthest apart? Are the isobars closer near the center or near the margin of the cyclone? In going in a direction across the isobars, where would you find the most rapid change in pressure, where the isobars are close or far apart? The rate of change is expressed by the *pressure* gradient, *i.e.* the change per latitude degree (about 70 miles in this latitude). The formula for determining the pressure or barometric gradient is

$$\text{Barometric Gradient} = \frac{\text{Difference in Pressure}}{\dfrac{\text{Difference in Distance}}{70 \text{ miles}}}.$$

As nearly as possible, the measurements must be taken perpendicular to the isotherms.

What is the barometric gradient between Chicago and Springfield, Mo.? Between Chicago and Nashville, Tenn.? Between Portland, Ore., and Tacoma, Wash.?

At each station where wind direction is given, draw an arrow, with the point showing the way the wind is blowing. How do they blow with reference to the cyclone and the anticyclone? Do they blow *directly* into or away from either? Do they blow at right angles to the isobars?

On a separate map, write the wind velocities at the

different stations. Compare the velocities in the cyclonic and the anticyclonic regions; the inner and the outer portions of the cyclone. Select ten stations in the cyclonic region where the isobars are close together and find the average wind velocity. Also ten stations where the isobars are farthest apart. How do the velocities in the two groups of stations compare?

On the first map draw isotherms; *i.e.* connect with a line all points having the same temperature, first writing the temperatures at the different stations. Where is the coldest locality? The warmest? What is the general trend of the isotherms east of the Rocky Mountains? Do isotherms on the average run east-west or north-south? How can the behavior of these isotherms be explained by wind direction? How would you explain the fact that New Orleans has the same temperature as Buffalo? Where do the isotherms make closed lines? Which is the warmer, the center of the cyclone or of the anticyclone?

On the first map, mark your arrows to show the state of sky. (See the symbols in the lower left-hand corner of a weather map.) How does the state of sky in the cyclone and the anticyclone compare? Where is it freezing? Where is it clear? Where, cloudy? Where is it raining? Where, snowing? Where are the winds light? Where are there strong winds? What is the season, summer or winter? Why do you think so?

*27. WIND DIRECTIONS IN CYCLONES AND ANTI-CYCLONES

Take a piece of tracing paper about six inches square. Draw a line from the middle of one side through the center, and draw a line at right angles to the first line and through the center of the sheet. Your sheet will be divided into four equal parts. Find a well-marked cyclone, place the intersection of the lines over the center of the cyclone, and copy the wind arrows of the cyclone. Do this for several cyclones and you will have a composite picture of wind directions in a cyclone. What is the general wind direction in each quadrant of the cyclone? On a separate sheet make a wind diagram for each quadrant as follows: find the number of winds from north, northeast, east, southeast, south, southwest, west, northwest. From a point, draw arrows in the various directions whose lengths are proportional to the numbers of winds. For example, suppose there are 10 winds from the north, 20 winds from the east, 15 winds from the west, and 5 winds from the south. The diagram will appear as in Figure 6. Do the winds enter the cyclone directly or spirally? Where is the "low"

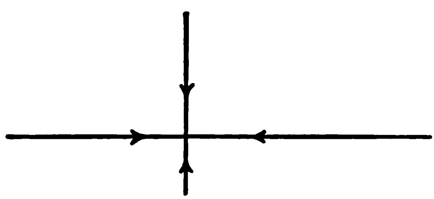


Fig. 6.

with reference to a south wind? A southeast wind? An east wind? A northeast wind? A west wind? Explain the *reason* for the "wind-barometer indications" found on the weather maps.

Work out in a similar manner the wind directions around a series of well marked anticyclones.

*28. ISOTHERMS IN CYCLONES AND ANTICYCLONES

Copy the isotherms in several well-marked cyclones and anticyclones on the same blank map. Do the isotherms pass through a cyclone in an east-west direction? Latitude alone considered, what would be the direction of the isotherms? Draw a generalized isotherm that will show the average directions of all your isotherms. How does the isotherm behave in passing from an anticyclone to a cyclone? How in passing *through* a cyclone? How are the curves of the isotherms correlated with wind directions?

*29. STATE OF SKY IN CYCLONES AND ANTICYCLONES

Following the same method, as in Exercise 27, study several well-marked cyclones and anticyclones east of the Rocky Mountains. Put a circle for clear sky, a shaded circle for cloudy sky, R. for rain, and S. for snow. You will thereby obtain a picture of the sky conditions in a cyclone and anticyclone. In general, how do the front and rear (east and west sides) of a cyclone

compare? Which winds are usually associated with cloudiness? Why? Which winds usually bring clearing weather? Why? What is the usual state of sky in and around an anticyclone?

30. INFERENCE OF A CYCLONE OR ANTICYCLONE FROM WIND DIRECTION

	Direction	Velocity
Duluth, Minn.	E.	16
Marquette, Mich.	N.E.	8
St. Paul, Minn.	E.	10
Sioux City, Ia.	E.	22
Chicago, Ill.	E.	26
Kansas City, Mo.	E.	14
Springfield, Ill.	N.E.	14
Grand Rapids, Mich.	N.E.	4
Detroit, Mich.	N.	14
Indianapolis, Ind.	N.E.	8
Knoxville, Tenn.	N.E.	4
Cairo, Ill.	N.E.	8
Elkins, W.Va.	N.	6
Washington, D.C.	N.	16
Philadelphia, Pa.	N.W.	12
Buffalo, N.Y.	N.W.	16
Albany, N.Y.	N.W.	12
Boston, Mass.	W.	14
Northfield, Vt.	N.W.	14
Parry Sound, Ont.	W.	8
Eastport, Me.	W.	26
Father Point, Quebec	S.W.	28

Indicate by arrows on a blank weather map the wind direction at the different stations. Are the winds due

to a cyclone or to an anticyclone? Fully state the reasons for your answer. Where is the center of the wind movement? Do the winds blow straight from this center? Which way are they deflected? Why?

Compare the wind average velocities in three localities: west of Lake Michigan, south of Lake Michigan and Erie, and southeast of Lakes Erie and Ontario.

What is the average of wind velocity in each group? Where do you think the barometric gradients are steepest? Least steep? What relation between the gradients and wind velocities?

31. INFERENCE OF CYCLONES AND ANTICYCLONES FROM ISOTHERMS

On a blank weather map, draw isotherms according to the following table: —

San Diego, Cal.	50°	Del Rio, Tex.	60°
El Paso, Tex.	50°	Winnemucca, Nev.	40°
Abilene, Tex.	50°	Flagstaff, Ariz.	40°
Fort Smith, Ark.	50°	Roswell, N.M.	40°
Chicago, Ill.	50°	Topeka, Kan.	40°
Detroit, Mich.	50°	St. Paul, Minn.	40°
Albany, N.Y.	50°	Devils Lake, N.D.	40°
Boston, Mass.	50°	Havre, Mont.	40°
Cape Henry, Va.	60°	Salt Lake City, Utah	40°
Wytheville, Va.	60°	Denver, Col.	30°
Indianapolis, Ind.	60°	North Platte, Neb.	30°
Little Rock, Ark.	60°	Valentine, Neb.	30°
Palestine, Tex.	60°	Cheyenne, Wyo.	30°

What isotherms make closed lines? Which extend entirely across the continent? From your previous studies, where would you infer there is a cyclone? Why? An anticyclone? Why?

Temperature gradients are found in the same manner as barometric gradients. Where are the temperature gradients steep in this map? Where gentle? What is the temperature gradient between Chicago and Indianapolis? Between Buffalo and Cape Henry, Va.? What do you think is the prevailing wind direction in Georgia? In Minnesota?

32. CONDITIONS IN DIFFERENT PARTS OF CYCLONES AND ANTICYCLONES

From March 1 to March 5, 1904, a cyclone followed by an anticyclone passed across the United States. The center of the cyclone was near North Platte, Neb., March 2; Buffalo, N.Y., March 3; and Halifax, N.S., March 4. The center of the anticyclone was near Eureka, Cal., March 2; Dodge, Kan., March 3; Indianapolis, Ind., March 4; and Eastport, Me., March 5. Indicate by a continuous line on a blank weather map the path of the cyclone center, writing the dates for the center at the proper stations. Show by a dotted line the path of the anticyclone and write the dates for its center. What is the average hourly rate of the cyclone's progress? Of the anticyclone?

The following tables give data for three stations: one near the paths of the centers, one to the north, and one to the south of these paths: —

	Pressure						Temperature					
	March 2		March 3		March 4		March 2		March 3		March 4	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
St. Paul	28.7	28.9	29.4	29.4	29.4	29.1	32	12	-2	21	4	28
St. Louis	29.2	28.9	29.6	29.8	29.8	29.6	42	69	22	30	26	37
New Orleans	30.0	29.9	29.9	30.1	30.2	30.1	67	72	66	55	40	54

	Wind Direction						State of Sky[1]					
	March 2		March 3		March 4		March 2		March 3		March 4	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
St. Paul	E.	N.W.	N.W.	N.W.	E.	S.E.	10	10	0	0	1	10
St. Louis	S.E.	S.	N.	N.W.	S.	S.E.	5	2	4	0	0	3
New Orleans	S.W.	S.	S.	N.	N.E.	S.E.	9	8	2	10	0	0

Draw graphs showing the pressures at the three stations. Which station shows the greatest pressure range? Why? How does the graph show the approach and recession of the cyclone at St. Louis? Why, at each station, is the pressure greater on March 4 than on March 2?

[1] In tenths of cloudiness; 0 indicates a clear sky, 10 a sky covered by clouds.

Draw graphs showing the temperatures at the three stations. (Place the dates about four large squares apart so that the graphs will extend well across the page.) Which graphs are most nearly parallel?

Write the wind directions along the temperature graphs at the proper places. What winds caused a rising temperature? A falling temperature?

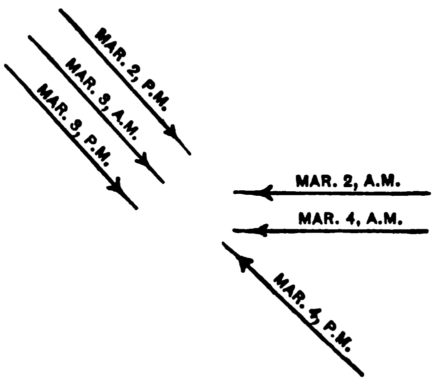


Fig. 7.

At each station show the wind directions as in Figure 7. At which station is there no south wind? Why? Why do the winds at St. Paul "back" from easterly to westerly winds? Why is there a southeasterly wind at St. Paul on the afternoon of March 4? Account for the winds at St. Louis. The winds of St. Louis on the afternoon of March 4 were caused by another cyclone. Where was its position? What is the predominating wind direction at New Orleans? How would you explain the northerly winds here?

In general, what winds at St. Paul and St. Louis give a clear sky?

33. CYCLONES AND ANTICYCLONES IN SUMMER AND IN WINTER

Look over several maps, both summer and winter. In which season do you find the cyclones and anticyclones best developed? What is the state of sky in front and rear of the cyclone in most of them? How does this compare with the anticyclone? In what part of the cyclone is rain most frequent in New England? In the Mississippi Valley?

In the winter cyclone from which part does a "cold wave" come most frequently? Find an anticyclone that produces a "cold wave." Do they usually produce a cold wave? In which, a cyclone or an anticyclone, are the barometric gradients usually steepest? In which are the winds usually highest, a cyclone or an anticyclone? Sketch a good example of a cyclone and anticyclone which produce cold waves.

Do the summer cyclones and anticyclones move faster or slower than in winter? In your locality which part of the cyclone brings cool weather? What kind of weather does an anticyclone bring? Find a period where there are practically no cyclones or anticyclones. What is the weather: quiet or windy? hot or cold? pleasant or oppressive? cloudy or clear? Is the rainfall, if any, general or local? Write a brief report on the above conditions specifying dates, places, and conditions.

*34. CYCLONE PATHS

If weather maps for one year, or for several years, are available, let each student trace the cyclones for one month. Follow each cyclone across the map and show the path of the cyclone center by a line. Then assemble the maps and draw: (*a*) the average annual cyclone path, (*b*) the average summer cyclone path, (*c*) the average winter cyclone path.

Which is the most northerly path, that for summer or winter? Where do cyclones usually leave the United States? About what percentage come from the northwest? From the southwest?

How would the climate be changed if the average cyclone path were east-west at about the latitude of Memphis, Tenn.? How if it were east-west through New Orleans?

CHAPTER V

MISCELLANEOUS CLIMATIC PHENOMENA

*35. A LAND AND SEA BREEZE. BOSTON, MASS. JUNE 27, 1908

	Wind Direction	Temperature		Wind Direction	Temperature
1 A.M.	W.	63	1 P.M.	E.	72
2 A.M.	W.	62	2 P.M.	E.	70
3 A.M.	W.	62	3 P.M.	E.	71
4 A.M.	W.	62	4 P.M.	E.	73
5 A.M.	W.	61	5 P.M.	S.E.	75
6 A.M.	W.	62	6 P.M.	S.E.	75
7 A.M.	N.W.	66	7 P.M.	S.E.	74
8 A.M.	E.	69	8 P.M.	S.	72
9 A.M.	S.E.	73	9 P.M.	S.	69
10 A.M.	E.	74	10 P.M.	S.W.	68
11 A.M.	E.	75	11 P.M.	S.W.	68
12 N.	E.	72	12 M.	S.W.	67

Plot the temperatures. About an inch above your graph, write the wind directions for each hour. When did the sea breeze begin? How long did it continue? Why did it blow during this time? When did the land breeze begin? How long did it continue? What is the reason for its occurence?

If the temperature were due to insolation alone, when would its maximum come? How does your graph compare with those in Exercise 14? How has the sea breeze modified the usual graph for daily temperature? Without the sea breeze how would the temperature graph for Boston probably appear?

36. A CHINOOK WIND

DENVER, COL., QUADRANGLE

On February 9, 1909, a well-marked chinook wind blew at Denver, Col. There was an area of high pressure in Arizona and an area of low pressure in eastern Colorado. The following table gives the temperatures, wind directions, and relative humidities at Denver on that day. On a blank weather map, indicate the locations of high- and low-pressure areas.

How is Denver situated with reference to the Rocky Mountains? Plot the temperatures. When is there a rise? How much of a rise? What change in wind direction nearly coincides with this rise? Does this wind direction usually produce a rise in temperature? Explain how it does in this case. How does the relative humidity change during the chinook? Explain this. How would the relative positions of the areas of low and of high pressure cause a chinook? How would the location of Denver favor a chinook? Would you think that chinooks are desirable in winter? Why?

	Temperature	Wind		Temperature	Wind
1 A.M.	1	S.E.	1 P.M.	29	N.W.
2 A.M.	1	S.E.	2 P.M.	32	N.W.
3 A.M.	0	S.E.	3 P.M.	30	N.W.
4 A.M.	1	S.	4 P.M.	30	N.W.
5 A.M.	1	S.	5 P.M.	28	N.W.
6 A.M.	2	S.W.	6 P.M.	28	N.W.
7 A.M.	2	S.W.	7 P.M.	28	N.W
8 A.M.	3	S.W.	8 P.M.	27	N.W.
9 A.M.	14	S.W.	9 P.M.	27	N.W.
10 A.M.	28	S.	10 P.M.	26	N.W.
11 A.M.	31	N.W.	11 P.M.	26	W.
12 N.	30	N.W.	12 M.	28	W.
Relative humidity A.M. 92; P.M. 48.					

*37. OBSERVATION OF A RAIN STORM

Date and hour? Direction and velocity of the wind? Is the storm evidently in a cyclone or an anticyclone, or is it local? What kind of clouds preceded the storm? What change, if any, took place in the clouds preceding and during the storm? How long did the rain last? Was it followed by a clearing sky? Were the drops large or small? Was there any difference in size of the drops at the beginning and at the end of the storm? Was it cooler or warmer during the storm? After the storm? How much rain fell? If possible, compare a summer and a winter rain storm in all the particulars noted above.

38. THE DEW-POINT

Take a bright tin cup. Fill with water at the temperature of the room. Put in a lump of ice and stir the water with the thermometer (be careful not to break the thermometer), watch carefully the surface of the cup, and record the temperature of the water at which moisture first collects on the outside of the cup. This is the dew-point. Why?

39. OBSERVATIONS UPON DEW DEPOSITION

Dew: Quantity (heavy or light). — Several leaves or blades of grass may be collected and weighed. After drying, they can be weighed again, and the difference in weights will show approximately the amount of dew. This weight can be reduced to inches or fractions of an inch. One cubic inch of water weighs about half an ounce. Care should be taken not to shake off any of the dew or to allow the plants to wilt. Note the things upon which dew collects (wood, stone, different plants, etc.). Temperature the night before. State of sky, movement of air. How long before the dew disappears in the morning. See if this has any relation to the air movements, the temperature, and the relative humidity. Place of observation (level or hilly; exposure in what direction; proximity of houses, trees, etc.). It would be interesting to compare the amount of dew, and the

rapidity of disappearance in a grove or forest and an open space.

40. STUDY OF A FOG

What is fog? What is its general cause? Where have you seen it occur? If over land or water, what is the apparent cause? How dense is it? (This is usually estimated by the distance one can see through the fog.) Does it disappear suddenly or slowly? Find out, if possible, at what time the fog began to appear. If you can see the upper part of the fog, estimate how thick it is. Does it occur in a valley or on a hill, or both? If possible take temperature readings to determine at what temperature it disappears, and if the temperature changes suddenly at the disappearance of the fog. Relative humidity readings would be interesting. Did you ever see a fog around a piece of ice or a water pitcher on a hot day? Explain. What effect has the fog on bodily sensations? On business (*e.g.* the fogs of London)?

*41. CLOUD STUDY

What kinds of clouds are visible? If more than one kind, what is the predominant kind? What percentage of the sky is covered? (Estimate in tenths.) What is the prevailing direction of cloud movement? How does this compare with the direction of the surface winds?

Tabulate these facts from observations made daily every two hours. Compare the clouds in morning, midday, and evening. If possible, get observations in winter and summer.

From your observations, note the predominant kinds of clouds and the percentage: (*a*) in front and rear of a cyclone, (*b*) in an anticyclone.

*42. OBSERVATION OF FROST CONDITIONS

Note the following conditions when frost has occurred: Is the frost light or heavy? What was the temperature before the frost? After the frost? If maximum and minimum thermometer readings are available, note them. Was the sky cloudy or clear? Was the air quiet or moving? What was the relative humidity before the frost? Was the locality subject to frost on a hill, in a valley, or both? What was the surface of the ground — stony, loam, clay, pavement, etc.? Is there any difference in the amount of frost on different objects? Did the frost occur in a cyclone or an anticyclone and in what part, east, west, north, or south, or was it local?

Write a concise report on these frost conditions.

Frost Forecast. — On several nights when you think that frost is likely to occur, observe and record the conditions named above. If frost does not occur, try to explain the factors affecting its non-occurrence.

43. MAP STUDY OF FROST CONDITIONS

	Pressure	Temperature	Wind Direction	Wind Velocity	Sky
Asheville, N.C.	30.3		S.E.	6	Clear
Elkins, W.Va.	30.3	50	N.W.	4	Clear
Albany, N.Y.	30.2	40	N.W.	14	Clear
New York, N.Y.	30.2	50	N.W.	16	Clear
Detroit, Mich.	30.2		W.	4	Cloudy
Nashville, Tenn.	30.2	60	N.E.	4	Clear
Charleston, S.C.	30.2	60	E.	14	Clear
Tampa, Fla.	30.1	70	N.E.	12	Cloudy
Mobile, Ala.	30.1	70	N.	8	Cloudy
St. Louis, Mo.	30.1	60	S.	12	Cloudy
White River, Ont.	30.1		W.	0	Cloudy
Montreal, Quebec	30.1		N.W.	12	Cloudy
Northfield, Vt.	30.1		N.	10	Clear
Corpus Christi, Tex.	30	70	S.E.	6	Clear
Oklahoma, Ok.	30		S.	12	Clear
Kansas City, Mo.	30		S.	10	Clear
Milwaukee, Wis.	30		S.W.		Rain
Duluth, Minn.	30	40	N.E.	12	Rain
Winnipeg, Man.	30		E.	4	Cloudy
Havre, Mont.	30	50	E.	4	Cloudy
Del Rio, Tex.	29.9		E.	8	Rain
Amarillo, Tex.	29.9	60	S.	18	Clear
Topeka, Kan.	29.9		S.E.		Clear
St. Paul, Minn.	29.9	50	E.	6	Cloudy
Miles City, Mont.	29.9		N.E.	4	Rain
Tacoma, Wash.	29.9		S.	4	Clear
El Paso, Tex.	29.8		E.	4	Cloudy
Dodge, Kan.	29.8	60	S.E.	18	Clear
Sioux City, Ia.	29.8	60	S.	4	Cloudy
Yellowstone Park	29.8		N.W.	4	Cloudy
Walla Walla, Wash.	29.8		E.	4	Clear
Reno, Nev.	29.8		W.	14	Cloudy
Yuma, Ariz.	29.8	60	N.W.	4	Clear
Flagstaff, Ariz.	29.7	60	N.W.	4	Clear
Pocatello, Id.	29.7		W.	4	Clear
Boisé, Id.	29.7		S.W.	8	Cloudy

Draw the isobars and isotherms. Where is there a cyclone? Where an anticyclone? Draw the wind arrows. Shade the areas where the sky is cloudy. Where and how many areas are there? How are these areas related to the cyclone and anticyclone? In general, which way do the isotherms bend, north or south? In this case, is this due to wind direction? If not, to what cause?

During the night previous to these readings, there was frost in western North Carolina and Virginia, West Virginia, Ohio, Pennsylvania, New York, and the interior of New England. Compare the frost area with the rest of the country as to the following factors, and state the effect of the factors on frost formation: state of sky, wind velocity, position in cyclone or anticyclone. Why should the interior, and not the coast of New England, be subject to frost? Other things being equal, which station would be more subject to frost, Havre, Mont., or Elkins, W.Va.? Explain what factors favored frost at Elkins and not at Havre.

*44. LOCAL FORECASTING

Note the weather maps for several preceding days. On the day preceding your forecast, was your locality in a cyclone, anticyclone, or was there neither? If there was a cyclone or an anticyclone, was it strong or weak? In what part of the cyclone or anticyclone was your

locality? What was its average progress per hour? In what direction was it moving? Were the barometric gradients strong or weak? Were the winds gentle or strong? Were the temperature changes around it slight or marked? What were the accompanying states of sky and precipitation?

From these data, forecast for your vicinity the temperature, wind direction and velocity, state of sky, and precipitation. If your forecast proves to be wrong, determine carefully the reasons why it is wrong.

If recent maps are not available, older maps can be used. Make at least one forecast for your vicinity in summer and in winter.

45. A STUDY OF OCEAN CHARTS: TRADE WINDS, ICEBERGS, FOG, AND SAILING ROUTES

A study of the pilot charts of the North Atlantic Ocean. Use the charts for January and July. If possible, use charts for all the months.

What department of the government issues these charts?

On a blank map, sketch the northern limits of the trade winds for January and for July. Through how great a distance do the trades here shift? Why do they shift? On the average, how wide is the belt between the northeast trades and the southeast trades? In general, is the region of tropical rains *within* one of the trade-wind

belts or *between* them? On your blank map, sketch its positions for January and July.

What is the prevailing wind direction in the two trade-wind belts? What other winds blow? About what is the *proportion* of winds from other than the prevailing directions? (See the "explanation," at the bottom of the chart.) How do the wind directions in the northern trade-wind belt compare with the directions north of this belt (the westerly drift belt)?

When in the year are icebergs most likely to be met? What effect does this have on the steamship routes between New York and London? Sketch these routes for January and July on your blank map.

Where are the regions of fog? Where is the principal region? When is fog most common, in winter or summer? About how large is the Newfoundland fog area in July? How would you explain the difference in size of the fog areas in January and July?

Sailing Routes. — Sketch the sailing route from London to New York. How and why does it differ from the steamship route? Sketch the sailing routes from New York to the equator and from the equator to New York. Contrast and explain them. Contrast and explain the sailing routes from England to the equator, and *vice versa*.

*46. LOCAL, INDIVIDUAL, OR CLASS STUDIES

(In all readings, it is well to have two or more persons make the readings so as to check results.)

Temperature. — Record the temperature at least twice a day during the school year. From the weather maps, determine the temperature gradient for each day.

Pressure. — Record the pressure at least twice a day, and from the weather maps determine the barometric gradient for each day.

Winds. — Record the direction at least three times a day. If there is access to an anemometer, get the wind velocities from that. If not, classify the winds as calm, gentle, strong, gale.

State of Sky. — Estimate, in tenths, the amount of the sky covered by clouds. Kinds of clouds and their direction of motion, if moving.

Relative Humidity. — Determine the relative humidity for each day, taking the readings at the same hour each day.

At the end of each week, bring the data together. Correlate the temperatures and wind directions. What winds bring warm weather? Cool weather? What relation between relative humidity and the temperature and wind direction? What relation between the state of the sky and temperature? Wind direction and pressure? What relation between barometric gradients and wind velocity?

CHAPTER VI

COMMON MINERALS AND ROCKS

*47. COMMON MINERALS

Most of the common minerals may be recognized by their physical characteristics. Color is usually somewhat variable, but the streak, that is, the color of the powdered mineral, is characteristic. Simply rubbing the mineral on a file will give the streak unless the mineral is very hard, in which case it may be powdered. Hardness is important and for rough work may be graded as follows: minerals easily scratched by the thumb nail are very soft; those not easily scratched by the thumb nail are soft; those that cannot be scratched by the thumb nail and are easily scratched by a knife blade are hard; and those that cannot be scratched by a knife blade are very hard. Cleavage is very important, but not all minerals show cleavage. Calcite has very good cleavage. The main things to note about cleavage are: In how many directions does it cleave (*e g.* mica cleaves in only one direction); at what angle do the cleavages run if there is more than one direction, and into what cleavage forms do they divide the mineral (*e.g.* the cleavages

of calcite are in three directions, and meet at oblique angles giving a rhombohedral cleavage form)? The cleavage can be ascertained by placing a dull knife blade against the mineral and lightly tapping the knife. Hold the knife blade at different angles and directions, to see if the mineral has any cleavages. If the mineral has a crystal form, this is very important to note. But the *crystal form* is to be distinguished from the *cleavage form*. If there is no cleavage, the fracture is sometimes distinctive. For instance, the shell-like or conchoidal fracture of quartz is an important characteristic. The weight, whether light, medium, or heavy, is important. If there is time and suitable apparatus, the specific gravity of the minerals may be found. Effervescence with weak hydrochloric acid is an indication of carbonates of which the principal common mineral is calcite.

Describe the following minerals as to color, streak, hardness, cleavage, crystal form, fracture, weight, action with acid, and other characteristics: quartz, feldspar, calcite, fluorite, barite, pyrite, hematite, magnetite, limonite, galena, hornblende, mica.

*48. ROCKS

Sedimentary Rocks

Shale. — Are its particles coarse or fine? How many different minerals can you find? Is it stratified? Laminated? Hard or soft? If ground up, would it make a

clay or mud? What is its color? To what does its color seem due? What seems to be the cement?

Sandstone. — Are the sand grains coarse or fine? What is the color of the sandstone as a whole? Of the sand grains? Is the cement calcite, an iron compound, or silica? How can you tell if it is calcite? (If an iron compound, it will usually stain the stone.) Are the sand grains angular or rounded? If the latter, what is the probable cause of their smoothness? Is the rock firm or friable? Hard or soft? Are there any traces of stratification in it? Of what mineral is the sand principally composed? Is it a pure sandstone or does it have lime or clay? Would it make a good building stone? Why?

Conglomerate. — What is the size of the largest pebble? What is the average size? What is the cement? What is the shape of the pebbles? Why? Is the rock as a whole hard or soft? Firm or not? Is there any trace of stratification? Are bedding planes more or less distinct in shales and sandstones than in conglomerates? Why?

Limestone. — How does it behave with acid? Why? Is the calcite crystallized so you can readily detect its physical characteristics? Powder some of the rock and dissolve it and note the residue, if any. (Usually a limestone contains a considerable amount of clay.) What is the color of the rock? Is it massive, or has it bedding planes?

Igneous Rocks

Granite. — Is its texture granitic or porphyritic (*i.e.* are all or only a part of its minerals distinctly crystallized)? What minerals can you determine? What are the principal minerals? What is the color of the rock? What minerals give its color? Would you describe the rock as a whole as hard or soft? Firm or friable? Do the minerals vary in size? If so, which are larger?

Diorite. — What is its texture? Color? Can you determine any of the minerals? Why is it harder to determine the minerals than in granite? Is it heavier or lighter than granite?

Basalt. — What is its color? Texture? Weight? Does it have as much quartz as granite? Are the black and heavy minerals more or less prominent than in granite? What minerals can you identify?

Obsidian. — How does its texture compare with that of granite and diorite? What is its color? What is the color of a powdered piece? Is it hard or soft? Compared with the other igneous rocks, is it light or heavy? Why can you not determine its minerals?

Metamorphic Rocks

Gneiss. — What is the color? What minerals do you find? Which of the igneous rocks does gneiss resemble so far as the minerals are concerned? How does the

arrangement of minerals differ from that of the igneous rocks? What minerals predominate? Is the rock as a whole harder or softer than granite? Will it ordinarily split more or less easily than granite? Why?

Schist. — Compare its structure with that of gneiss and the igneous rocks. What minerals do you find? How does the amount of quartz compare with that of granite? Of basalt? Is it harder or softer than gneiss? Would it split more or less easily than the igneous rocks? Why? What minerals predominate?

Quartzite. — What is its composition? How does it differ in appearance from sandstone? How does its hardness compare with other rocks? Does it split easily? Why?

Slate. — Does it have planes along which cleavage is easy? What other rocks show this? Is the cleavage better or poorer than in the other rocks? What is its hardness? Of what do you think it is composed? What uses has slate? To what properties are these uses due?

Other things being equal, which do you think would weather the faster, limestone or sandstone? Sandstone or shale? Sandstone or granite? Granite or schist? Building stone must stand a high pressure and should be massive, so as not to present opportunity for uneven weathering. So far as utility is concerned, which do you think would make the best building stone, granite

or gneiss? Gneiss or schist? Massive or bedded sedimentaries? Which rocks do you think would be better looking for building purposes?

*49. FIELD STUDY OF A ROCK OUTCROP

How great a thickness of rock is exposed? How great an area? What kind of rock is it, igneous, sedimentary, or metamorphic? How many varieties can you find? Do you find any joints? Note and report all features which you can find.

CHAPTER VII

THE CONTOUR MAP

*50. CONSTRUCTION OF A CONTOUR MAP

PART I. — The region selected should have steep and gentle slopes in proximity. Materials needed: drawing pads, ruler, compass, protractor, and some kind of a level.

Two things must be decided on before mapping: the scale and the contour interval. The scale indicates the distance on your map that will represent a given distance of your area. If the area is small, a scale of 20 feet to the inch is convenient. This is expressed by the fraction $\frac{1}{240}$. The contour interval will vary with the heights to be represented, but an interval of 5 feet is convenient, since that is about the average distance from the eye to the ground. It is well to measure a straight line on some level portion as a base line, AB, Figure 8.

From this base line points can be determined in two ways. If the point is near and easily reached, as points C and E, their direction can be taken from A or B, the distance measured, and the points determined on a map by a protractor and ruler. For instance, if C is south,

west 20° and 15 feet distant from B, it is located by drawing on the map an indefinite line from B at the proper angle, and then laying off the distance according to the scale adopted.

If there is a more distant point which is not conveniently reached, its angles at A and B can be found by the protractor, and these plotted on the map until their sides meet and the point D is located. Various members of the class can get distances and directions from trees, etc. A and B and these other points can be plotted later if desirable.

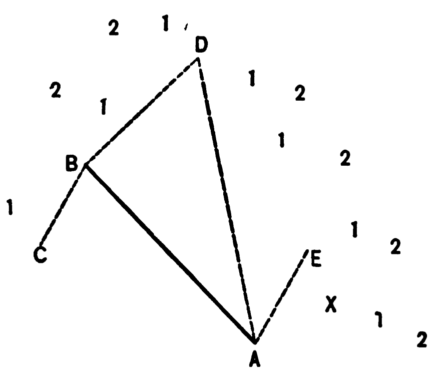


FIG. 8.

When several points have been located, *e.g.* trees, rocks, etc., the work of locating the contours can be begun. At the lowest place in your area, say, point X, let some one stand at X and level to different places on the area, while others mark these places, *e.g.* with pieces of paper (1, 1, 1). The leveling can be done with an instrument or by looking across the water in a tumbler. The points 1, 1, 1, all lie on a plane about 5 feet above X, and these points can be located as described above. Many of them can be put in with

sufficient accuracy by sketching. When enough have been located, connect them, and you have your first contour line. A second can be made in like manner, by standing at one of the points 1 and repeating the process, locating points 2, 2, etc.

STUDY OF A CONTOUR MAP

Lockport Quadrangle, New York

(It would be well to substitute the home quadrangle if it is mapped.)

PART II. — What is the scale? How many inches in the region does 1 inch on the map indicate? How many miles? What is the area of the quadrangle? What is the contour interval? What does the contour interval mean? Where are the contours close together? Where farthest apart? What represent Streams? Railroads? Roads?

Starting south from Lockport, how far is it along the road to Millersport? What do the figures 605, 601, and 586 mean? Where do you cross the 600-foot contour line? How far south do you have to go to reach it again? Trace it as far as possible on the map. Where does it cross the Erie Canal? If the sea should rise 600 feet, what relation would it have to this contour? In passing from Millersport to Lockport are you going uphill or downhill? How do you know from (1) the contours, (2) the streams? At what height is the contour line north of Mud Creek near Millersport? How far is

it from Mud Creek north along the Lockport-Millersport road to the 600-foot line? To the 620-foot line? To the 640-foot line? Make a profile along the road from Millersport to the 640-foot line. (Starting at Millersport, measure to the 580-foot line. It is about one eighth of an inch. Draw a line this long on your cross-section paper. Measure the distance to the same contour line across the

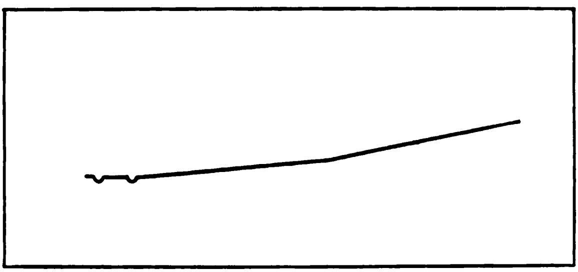


FIG. 9.

creek. Let each vertical square on your paper represent 20 feet. We cannot tell the depth of the creek between the contours, except that it is not 20 feet. Why? From this line measure to the next 580-foot line at Mud Creek. Here, again, we do not know the depth of Mud Creek below this line, so we are at liberty to put it at any depth below one square as we think best. (See Figure 9.) From the contour north of Mud Creek to the 600-foot line is 2 inches and *one square* higher. From this point to the 640-foot line is $1\frac{1}{16}$ inches and a square higher. The profile will be as shown in Figure 9.)

You will note that the vertical scale is different from the horizontal scale. Which is the larger? What fraction expresses the horizontal scale? What the vertical scale? Why, on this profile, is it necessary to exaggerate the vertical scale?

Would you call this region smooth or rough? Its slopes steep or gentle? How far is Raymond (northeast) from Millersport? How high above the sea level is the hill northeast of Raymond? Are its northeast and southwest slopes equal? At a point $2\frac{1}{4}$ inches from the east side of the map and 5 inches from the north side make a profile to the north 5 miles long. How does it compare with the first profile? What differences in level? Is the slope gradual or irregular? How high is the escarpment? What is the average slope per mile over the escarpment from the 600-foot line to the 500 foot line? When the contours are far apart, what does that show as to slopes? When close together? Which way does Tonawanda Creek flow? How do you know? (Note where the 600-foot line and where the 580-foot line cross it.) Where are its slopes steepest, in the upper or lower course? Do contours point up or down a valley? Why? Do they point up or down a ridge? Why? Find slopes of principal valleys; of the various escarpments. In any maps always determine contour interval and scale before reading them.

Problems. — (It is not to be thought that the drawings

should be alike. They may look unlike and yet fulfill the conditions of the problems.)

1. Draw a hill 2 miles long and 1 mile wide at the base and 100 feet above the surrounding country. (Use a 25-foot contour interval.)

2. A hill of the same dimensions with —

   (*a*) steep slope on the north and gentle slope south.

   (*b*) steep slope on the south and gentle slope north.

3. Two level surfaces separated by an escarpment 200 feet high (50-foot contour interval).

4. Using a contour interval of 20 feet, draw a hill 200 feet high above a plain, with a slope to the north of 200 feet to the mile and to the south of 400 feet to the mile.

5. Using a contour interval of 25 feet, draw a valley with an average slope of 25 feet to the mile; of 50 feet.

6. Draw a valley in a level plain 75 feet deep near its head and 200 feet deep at its mouth.

7. Using a contour interval of 20 feet, draw a valley with a slope of 40 feet to the mile, its head being 20 feet below the surrounding country and its mouth 100 feet.

F

CHAPTER VIII

WEATHERING, STREAMS AND STREAM VALLEYS

*51. FIELD STUDY OF WEATHERING. A VISIT TO A QUARRY OR ROCK OUTCROP

WHAT kinds of rock? Hard or soft? Is it homogeneous (of the same kind) or of different kinds? Is it stratified or massive? Are the fresh fractures smoother or rougher than the older fractures? Why? (The answer will depend upon the kind of rock.) Are sharp edges and corners more or less weathered than the flat surfaces? Why? Which exposes the most surface to weathering, the corners or the flat surfaces? Are there joints in the rock? Are the joint planes weathered? Why? If you can observe limestone, are there any cavities? Is there any evidence of iron (stains)? Observe all the instances you can of the work of the oxygen and carbon dioxide of the atmosphere. What is the depth of the soil? What is its color? To what is any dark color due? Is it derived from the underlying rock? How do you know? What effect has the decay of vegetable matter on the ability of the ground water to accomplish weathering? Can you find examples?

Do you find any examples of weathering work by trees? By animals? By frost?

Break off a piece of rock. How do the fresh and the weathered surfaces compare? How deep is the zone due to weathering visible? Is this part of the rock stronger or weaker than the fresh part? Why?

Visit a rock exposure in winter. Do you find examples of the prying effect of ice? Pick off a piece of ice from the rock surface. Is the contact side clean? Why? What bearing on ice work has this fact?

Soil. — Is it mostly of sand? Or clay? Or gravel? Or a mixture of sand and clay (loam)? In each case from what kind of rock could it have come?

*52. FIELD STUDY OF STREAM WORK

How wide is the stream? How deep? What is its slope in 100 yards? What is its average slope per foot? At this rate what would be its slope per mile? (The slope can be determined by leveling along the water's edge in the same manner as shown in Exercise 50.) What is the velocity of the stream per mile? (Note the time it takes a floating object to pass over a measured distance.) In the straighter courses of the stream where is the fastest current, at the sides or in the middle? What is the velocity in the middle? At the sides? Note the same points in the meander of the stream. Make a

diagram of the straight course and of the meander, showing the "thread of the fastest current."

The Stream Load. — Is the stream at present carrying a visible load? (If not, visit it during high water.) Of what does its load consist, mud, sand, or pebbles, or all of these? Where is the stream water clearest, in places of swift or slow current? Why? Is there any gravel? If so, of what material? Is it angular or round? Do you think the gravel has been rounded by the stream? (This should be answered with caution in a glaciated region.) What is the *average* weight of the pebbles that the stream moves? What is the weight of the largest rock that the stream has moved?

The stream's invisible load may be detected by allowing a drop of the water to evaporate on glass. What is the color of the residue? Test it with acid. If there are laboratory facilities, evaporate a given quantity of water and determine the weight and composition of the invisible load.

Stream Erosion and Deposition. — Is the stream at the place of observation eroding, depositing, or at grade? What has it been doing in the past? How do you know? Are there flood plains? If so, how wide? Do they slope toward the stream or away from it? Does the flood plain join the valley side by a gradual or a steep slope? Of what material is the flood plain composed? Does the flood plain material differ in kind or in fineness as

you go away from the stream? Does the flood plain slope downstream? Does it slope at the same rate as the stream? Are there bars in the stream? Can you account for them? What are they composed of? Examine the work of a stream in a meander. Where is it corrading? Where depositing? Contrast with stream work in a straight reach. Examine several meanders and note the stream action at points *A*, *B*, *C*, *D*, *E*, and *F*, Figure 10. Does a meander as a whole move up- or downstream, or is it stationary? Why do you think so? Do you find any meander that has moved downstream, thus opening up the valley (lateral planation)? If so, describe it. If you find a well-developed meander, describe as to length and steepness the slopes at *GF*, *GE*, and *GD*.

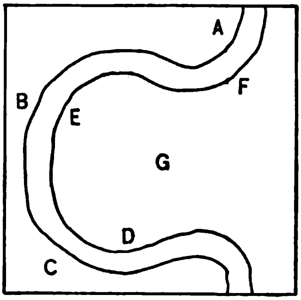


FIG. 10.

The Stream Valley. — How wide at the bottom? At the top? How deep is the valley? Do you think the valley is due to the work of the stream or not? Why? Does the valley follow all the curves of the stream? Does it follow the main curves? Is the valley narrow or wide at the bottom as compared with its top? Is its section *V*-shaped or *U*-shaped?

Are the valley sides perpendicular, nearly perpendicu-

lar, or sloping? If sloping, is the slope uniform? What is the average slope of the valley sides? (Hold a clinometer so its base coincides with the sky line of the valley slope, and read the inclination. A common protractor can be used, or a serviceable clinometer can be made on the inside of your notebook cover, Figure 11. A button

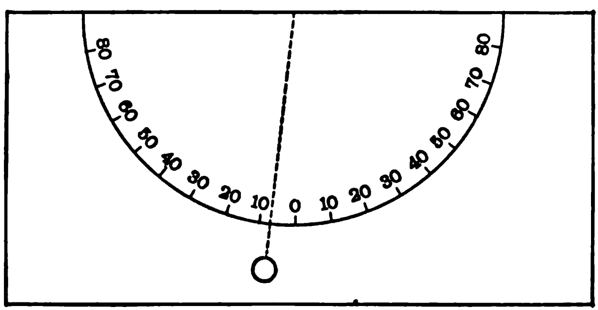


FIG. 11.

or half of a bullet will make a good weight.) Is the slope at the bottom as steep as at the top? Why? Are there marked changes in the slope? If so, are they due to a difference in rock? Are the two valley slopes equally steep in the straight reaches? In the meanders of the valley? Are there cliffs? If so, to what are they due: to differences in the rock or to stream work at the base? If the former, make a sketch of the rock arrangement; if the latter, explain in full.

Is the top of the valley wider or narrower than the bottom? How much? Give all the reasons for this

that you can. Which are most important? In which part, the top or the bottom, is weathering the more important? Corrasion? Which part has been longer exposed to weathering?

Stream Tributaries. — Does the tributary valley at its junction with the main valley point up or down the latter valley? At what angle? (This can best be determined from a good map if one is at hand.) Does the valley narrow or widen as you go up it? Give all possible reasons for your answer. Do the slopes of the valley sides change as you go up? How? Why? Make cross sections of the valley in its lower and upper portions. Select a short valley, level up the valley as described in Exercise 50, and, from your data, plot a longitudinal profile of the valley. Is the curve as a whole concave or convex to the sky? Where is it steepest? Where least steep? Why? Are there any sudden changes in the curve causing rapids or waterfalls? If so, explain the cause.

Does the tributary stream enter the main stream at grade? Can it erode below the level of the main stream (its local base level)? Compare the corrasion and deposition of the stream in its upper and lower portions.

Does the stream reach the ground water level at any place (shown by springs)? Is there a different ground water level for wet and dry times? Is the stream intermittent in any portions of its course? Why?

Interstream Areas.— What is the width of the area between streams? Does it slope gently or sharply to the streams on either side? Describe the dissection of its surface. Does the amount of dissection change in passing away from the main stream?

Is the divide distinct or indistinct? Broad or narrow? Flat or with marked slopes? Does its distinctness change in going towards or away from the main stream? Is the divide midway between the two streams on either side? Toward which stream is the divide likely to migrate? Why?

53. WEATHERING AND CORRASION CURVES

Weathering Curve.— Assume the block *ABCD*, Figure 12, to be of uniform composition and exposed to uniform weathering on all sides. In this process the block will be reduced in size. Will it retain its rectangular shape? What did you determine as to this in your field study of rocks with sharp angles and monuments with square corners?

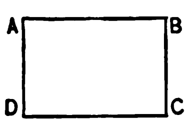


FIG. 12.

Why do corners tend to become rounded? Will the curves of the block *ABCD* be convex or concave to the sky? Such curves are called weathering curves.

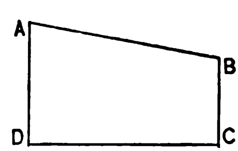


FIG. 13.

Corrasion Curve. — Assume block *ABCD*, Figure 13,

homogeneous as in Figure 12 and having a slope *AB* with a rainfall equal on all portions of the slope *AB*. In which way would the water run, toward *A* or *B*? Would the volume of water be the same at *A* and *B*? What effect would this fact have on the comparison of the erosion at *A* and *B*? What part of the line *AB* would be eroded most rapidly? What kind of a curve would the line *AB* be at first? After considerable period of erosion? Would it be concave or convex to the sky? What effect would such a curve have on the velocity of the water at *B*? What effect would this in turn have on the erosion in the vicinity of *B*? Such a curve is called a *corrasion curve.* Is this corrasion curve steeper in the vicinity of *B* than in the vicinity of *A*? Why?

These type curves require a homogeneous material. If your region is composed of materials of different degrees of resistance, the curves will be complicated, but can usually be recognized.

Note the hills and valleys along the route of your field trip. Where, near the top or near the bottom of the hills, are weathering curves prominent? Corrasion curves? Note either of these curves on the valley sides. Sketch in contours examples of both curves. Which curve, the weathering or the corrasion curve, does your stream profile of Exercise 52 most resemble? How would you explain your answer?

*54. STREAMS AND STREAM VALLEYS. GENERAL MAP STUDY OF STREAMS AND THEIR VALLEYS

If the home area is mapped, note the following points on the local map: —

What is the main stream valley? How deep is it? How wide? Is its depth uniform? If not, where is it deepest, in its upper or in its lower portion? Is it uniformly wide? If not, where is it widest, in the upper or in the lower portion? Which portion of the stream, the upper or the lower, has the greatest volume of water? Why? What evidence of this in the width of the stream? In the width of the valley? Which portion of the stream valley is the oldest?

(Beginning at the lowest contour in the valley, represent its position by point 1. Measure the distance up the valley side to the next contour line, transfer the distance to your coördinate paper and you have, say, point 2. In like manner get points 3, 4, and 5, as in Exercise 50, Part II. Connecting these points, you have a profile of one side of the valley. When the other side is completed, the two profiles give the valley cross section.) Which part of the valley has longest been subjected to weathering? What relation has this fact to the width of the valley in various parts?

Make a cross section of the valley in its lower and in its upper part. (Use cross-section paper, allowing each small square to represent one or more contour intervals.

If the relief is great a small square may represent *several* contour intervals so as to avoid too much exaggeration of altitude. The horizontal scale of your section is true, but your vertical section is exaggerated. How much is it exaggerated? In such work the exaggeration should be the least possible and yet bring out the essential details. The student must develop his judgment as to the exaggeration of the vertical scale.) In which portion of the valley, the upper or the lower, are the slopes the steepest? Account fully for this.

How long is the valley? How far is it in a *straight* line from its mouth to its head? What is the altitude at or near its head? At or near its mouth? What is the average slope per mile? Is the slope uniform? If not, where is it steepest? Make a longitudinal profile of the valley. (Unless the relief is great, allow one small square to represent the contour interval. If the valley is too long for your cross-section paper, the horizontal scale will have to be diminished in transferring to your profile. A convenient way is to transfer to the profile only half the distance on the map. Construct in the same way as in the valley cross section of this exercise.) Is your curve concave or convex to the sky? Where is it steepest? Why? Does the steepness increase uniformly from the mouth to the head? What are the reasons? What is the slope per mile in the steep portion? In the more level portion?

About how many square miles are included in the drainage basin of the stream? Are there any tributaries? How many? What is their average length? Are the tributaries of the tributaries well developed? In general, do the tributary valleys point up or down the main valleys? Do they all join the master streams at grade? Does the stream follow a straight or a winding course? Does it meander in any portion? If so, what, the upper or lower? Do the curves of the stream *always* correspond to curves of the valley? If not, where is there the least fitting of stream and valley curves, in the upper or the lower portions? In the steep or the more level portions?

If there is no local map available, the following quadrangles will afford good examples: New Martinsville, Ohio; Highwood, Ill.; Pittsburg, Pa.; Marshall, Ark.; Guyandot, W. Va.-Ohio.

55. REVERSED TRIBUTARIES

New Martinsville Quadrangle, West Virginia–Ohio

How far and in what direction from Cincinnati? Pittsburg? At what angle do most of the tributaries to the Ohio point? Do they point upstream or downstream? Which way do the tributaries of the tributaries point? Make a sketch map showing the Ohio and its main tributaries, and one showing Fishing Creek and its tributaries. How do they compare? The

Ohio in this region is thought to have at one time flowed northward. What evidence of this former direction of flow is shown in this region?

*56. A BRAIDED (ANASTOMOSING) STREAM

Lexington Quadrangle, Nebraska

In what part of the state is this region? What part of the Platte River is here shown (upper, middle, or lower)? Is the Platte River, as a whole, aggrading or degrading? Why do you think so? How wide is the belt subject to overflow at high water? How wide is the trench in which the river flows? How deep? How far below the bottom of this trench is the river? Does the water usually run in one or many channels? Do you think that the map was made when the river was in flood? What is the average slope per mile on the stream? Is this high or low as compared with most rivers? Do you think, therefore, that the aggradation is caused by a change in slope or a change in volume? Is the rainfall here heavy or light? What bearing does this fact have on the preceding question? Was the river following its present habit when it cut the deep, wide trench in which it flows? Give a verbal picture of the river as you would see it looking up from the Lexington bridge. How is it similar to the streams with which you are familiar? How is it different?

Ishawooa Quadrangle, Wyoming

Trace the Shoshone River. Where is it degrading? Where aggrading? What is its slope in feet per mile where it is degrading? What, where it is aggrading? Make a profile of the river marking the stretches where it is aggrading and where it is degrading.

*57. FLOOD PLAINS. AN AGGRADING RIVER. NATURAL LEVEES

Donaldsonville, La., Quadrangle

How far and in what direction from New Orleans is Donaldsonville? In general, how wide is the river here? Why can you not tell the width of the flood plain from this map? Where, with respect to the river, is the highest land? Where, the lowest? Why is the country highest near the river? How wide is the natural levee here? Make a profile across the river and levees at Lilly. Are the slopes steepest towards or away from the river? Explain fully the reasons. What is the slope in feet per mile from the top of the natural levee toward the river? From the river? How high is the back swamp above sea level?

Do all the tributaries run directly into the Mississippi? Do most of them? Why? Is New River an aggrading or degrading stream? Is its natural levee higher or lower than that of the Mississippi? Where do most of the people live? What is the direction of a majority

of the roads? Do the numerous canals drain toward or from the river? Why? In 1890 the levee near Nita Crevasse broke. What connection between this and the irregular hills to the northeast? Are these hills round or elongated? Why? How high are they? The Indian mounds are thought to have been built for refuge in flood time. How high are they? Where is the river most likely to break through the levee, at Nita Crevasse or Brilliant Point? At Burnside or Cofield? Why?

Marysville, Cal., Quadrangle (Edition of January, 1895)

How far and in what direction is Marysville from San Francisco? Where does the Sacramento rise? Into what does it flow, and where? What height must an elevation in this map have to be shown by contours? Why is so large a contour interval used? What features has the Sacramento in common with the Mississippi at Donaldsonville? How wide is the flood plain? The natural levee? The back swamps?

*58. A GRADED RIVER

Elk Point Quadrangle, S.D., Neb., Ia.

The Missouri River in this region is practically at grade. Is it markedly deepening its channel? Is vertical or lateral corrasion most prominent? How does it compare in this respect with the Ohio River in the New Martinsville region? How does it compare

with the Platte? How wide is the flood plain in general? How far below the uplands? About how far is the river surface below its flood plain? What is the river's slope between Vermilion and Ponca? Would all streams meander with such a slope? What, therefore, do you infer about the load of the Missouri? Is the river now widening its valley at any place? Where? How? How far is it from Vermilion Ferry in a straight line to where the river leaves the quadrangle? How far is it, measuring along the river? What is the origin of Lake McCook? Is its curve of larger or smaller radius than those of the river? Why should they be so? What does the slough southwest of Burbank indicate as to the former course of the river? What is the probable origin of the slough near Elk Point? Why does the Big Sioux turn and flow parallel with the Missouri? What recent cut-offs in the Big Sioux? Has the Big Sioux a higher or lower slope than the Missouri? Is the Missouri corrading its valley sides? (This process has been termed lateral planation.)

59. MISSISSIPPI DELTA

East and West Delta, La., Quadrangles. Coast Chart, No. 194. *Scale* $\frac{1}{80000}$

What are the scales of these maps? Why is there no contour interval for the relief maps? About how many square miles are included in the delta country

from Head of Passes Light? How much land above sea level? Through how many main distributaries does the river discharge? Does it discharge through other distributaries above these? Make a sketch map showing the arrangement of distributaries. What is the width of each of the three distributaries? About what is their depth? Where are they deepest, in their upper or lower courses? Why? Where would a ship have greatest difficulty in entering? How is the ship channel improved in the South Pass? Why are jetties built at the mouth of the pass? What is the depth of water in them? What is the depth of water in the mouths of the other passes? How long are the jetties? Why is a dam placed at the head of Grand Pass?

Taking the delta as a whole south of the junction of the passes, is it triangular? Is the same outline to be seen at the mouths of any of the distributaries? Is the land at the forks triangular? What explanation? Taking the delta as a whole, does it slope uniformly beneath the water? (For answer make a profile from the head of the passes on Garden Island Bay or East Bay to the 10-fathom line.) Allow each small square to represent 1 fathom. Note the values of the figures within the dotted surface. Where are the most gentle slopes? At what depth is the steepest slope? What is its slope per mile? Take a subordinate delta, such as that at the mouth of Pass à Loutre, or that at the

junction of Northeast Pass and Southeast Pass (southwest of Blind Bay), or that at the mouth of Southwest Pass, and make a profile. How do the slopes compare with those of the delta as a whole? How many marked slopes in all of them do you find? How much change in sea level would leave most of the delta dry? How much would submerge all? Are there lakes included in the delta? What?

60. ALLUVIAL FANS

Cucamonga, Cal., Quadrangle

* PART I. — How far, and in what direction from San Francisco? From Los Angeles? What divisions of this region could be made on the basis of altitude? What is the general height of the highlands? What is the difference in altitude of highlands and lowlands? In how many miles does their change of altitude occur? What, therefore, is the slope per mile between them?

Make a profile along San Antonio Valley from the 4500-foot contour to the 750-foot contour. What is the average descent per mile of the profile? What is the descent in the cañon? Below the cañon? What effect would this change in slope have on the velocity of the stream? Upon the carrying power? Where is the stream evidently degrading? Where aggrading? How far below the mouth of the cañon do the contours *bow out?* How long is the alluvial fan built by the

stream? How wide at its widest part? What is its approximate area in square miles? (The area of a triangle is one half the product of its base by its altitude.) What is its approximate area in acres (640 acres in 1 square mile)? Where does the stream disappear in the fan? Where does it reappear? Does it reappear as a single stream? How far between the disappearance and the reappearance? Where would you infer that the stream would drop its heaviest and coarsest load, at the apex or the margin of the fan? Why? Why, therefore, does the stream disappear at the apex of the fan? What is the slope of the fan? The horizontal outline? The general shape? How do these compare with similar features of the Mississippi delta?

Are there other fans? How many? Which is the largest? Which has steepest slopes? Which is the smallest? Which stream has the largest drainage basin? Which, the smallest? Is there any relation between the size of the drainage basin and the size of the fans? Are the fans distinct from each other? At about what contours do they seem to coalesce? Such coalesced fans are sometimes called *peidmont* or *compound* fans. Which are the most dissected, the fans or the mountains? Which are the youngest in actual age? Which in *stage* of erosion? What inference as to the rainfall of the region can you make from: the intermittent streams; the number of streams;

the dissection of the fans? What can you say of the water-power facilities in the mountains? Upon what part of the fans are most of the towns? Sketch a typical fan.

BRAIDED RIVER AND ALLUVIAL CONES

Corona Quadrangle, California

PART II.—What is the fall per mile of the Santa Anna River from the northeastern part of this area to the town of Yorba? From Yorba to near Garden Grove? From near Garden Grove to the sea? Where has this river built an alluvial fan? How wide is the fan? What is its slope per mile? Do all of the flood waters of the river pass through its present channel? What channel to the north is sometimes used? Where does the river fill its channel? Where does it become "braided"? How does its slope explain its braiding? How does the material through which it flows? Where does Santiago Creek become braided? How does its slope in the braided reach compare with that in the upper course? How would you account for this? Describe the gentle slopes south of Corona with their drainage. Are most rivers braided in their lower course, as the Santa Anna? Why? In what part of its course is the Platte braided? From the size and number of streams and the number of tributaries, can you infer the rainfall of the region?

In what physiographic regions is population dense? What means of irrigation do you find? Trace the Orange and Santa Anna Canal.

61. RIVER DEPOSITS. BARS

Almost any chart of the Mississippi River will show bars. The charts below Cairo are especially good. The following charts are useful: numbers 7, 8, 10, 16, or 20 (charts of the Lower Mississippi, scale $\frac{1}{20000}$). How many bars do you find? What is their average length? Width? Are they rounded or elongate? Do they occur for the most part at the sides or in the middle of the river? Why? On a meander, do they generally occur on the inside or the outside of the meander? Why? Is a bar often formed where a tributary enters? Why? Do they occur on the upstream or the downstream side of the tributary? Why? How high, in general, are the bars above the water? Find and sketch a type bar in a straight reach; in a meander; at the entrance of a tributary.

62. FLOOD PLAIN MEANDERS

*Part I. — The following charts of the Mississippi River show meanders and their accompanying phenomena: numbers 13, 14, 20, 18, 8, scale $\frac{1}{20000}$.

How is the depth of the river shown? The elevation of the land? Make a profile of the river bottom

across the river, at the beginning, middle, and end of the meander. Where is it deepest at these points? Where is it cutting most? Where, with respect to a "tongue" (the land extending into a meander), is the river depositing in most cases (upstream or downstream from the "tongue")? Are there any cut-offs? If so, are they filled at either end? Does the resulting oxbow lake show the same shaped bottom as the meanders in the present stream? What is the length of the oxbow lake? How much did the river shorten its course when the oxbow lake was formed? How does the curvature of the oxbow lakes compare with that of the meanders? Are there any impending cut-offs? How much has the river yet to do to cut through the base or "neck" of "tongues"?

Bayou Sara Quadrangle, Louisiana

PART II. — How far is this region from the mouth of the Mississippi? About how high is the river above sea level? About how wide is the river? Trace the levee. Why is there no levee on the east side of the river? About how wide is the valley between the levee and the upland on the east? What is the general altitude of the upland?

How long is False River? What physiographic term would apply to it? How wide is the old "tongue" through which the Mississippi has cut? How much

did the river shorten its course? Do you infer that the cut-off is recent? Why? What fraction of False River has been filled? How high is the filled portion above the present False River? How does the altitude of this part compare with that of the surrounding country? Has False River any outlet? Which way does Grand Lake drain? Note the streams flowing northward in the region south of False River. How do many of them end? Why? How does the curvature of False River compare with that of the present meanders? Does Bayou Sara empty directly into the river? How high is the cliff west of Springfield Bend? How far can you trace it? What made it? Take any chart (scale $\frac{1}{63360}$) of the Mississippi River. Note the meaning of the red lines and the black lines. Where has the river *built* its banks? Where has it *cut* its banks? Does this occur for the most part in the straight or the curved portions of the river? Which process, for the most part, occurs on the upstream side of spurs? Which on the downstream side of spurs? Sketch good examples. What landings have changed their position, and why?

63. RIVER TERRACES

*PART I. *Hartford Quadrangle, Connecticut.* — The river terraces of this region are best shown between East Windsor and Burnham. How wide is the first terrace? How high above the river? How high is the terrace

front? What is the direction and amount it slopes per mile? How high above the first terrace is the second terrace? How wide is it? How far along the river can you trace the first terrace? How high is it above the river at East Hartford? At South Windsor? At East Windsor? At the Warehouse Point? Can you trace it on the west side of the river? Which way does the terrace slope? Why? Was the river aggrading, or degrading, when the terrace was built? Which is the river doing now?

PART II. *Peoria Quadrangle, Illinois.* — The city of Peoria is built on a terrace. How high above the flood plain? How broad? Does it slope toward the river? Away from the river? How could you explain the depression in the northwestern part of the city? How would you explain the bluffs back of the city? How high are the bluffs? Is there a corresponding terrace down the river? Compare it in all respects with the one in which Peoria is situated.

Sketch the best type of a terrace you can find. Note the levees in different places.

64. STREAM CAPTURE

*PART I. *Kaaterskill Quadrangle, New York.* — How far, and in what direction, from New York City? Note the escarpment of sandstone and similar rocks running across the map. How high is it? How steep is it?

Is it dissected? How many streams run across the escarpment? Do they extend far back of the escarpment? Trace the divide between the easterly and westerly flowing streams. How far is it from the escarpment? Which streams, the easterly or westerly flowing, have the greatest fall per mile? Which way would you expect the divide to migrate? Why? At what kind of an angle do the tributaries enter Schoharie Creek? Plattekill Creek? What is the usual normal angle? Taking the valley of the Plattekill, west of West Saugerties, compare its cross section in the Clove and above the Clove. Where is the valley widest? Deepest? Where are the sides steepest? Do the lower and upper parts of valleys usually have these characteristics, or are they usually reversed? If the Plattekill were to capture portions of the Schoharie, would the present arrangement of valley tributaries in the upper Plattekill, be explained? Judging from the angle of its tributaries, where did the Plattekill begin to capture the Schoharie? Assuming this process of capture to continue, sketch the probable stream pattern of the Plattekill when it shall have captured the upper Schoharie at about one mile southwest of the Plaat Clove P.O. Has the same process been in operation on the Kaaterskill Creek? Into what were South Lake and North Lake probably tributary? Judging by the tributaries, where did the process of capture begin? Can

you find any impending captures? Sketch the present drainage of Kaaterskill, Schoharie, and Plattekill creeks in continuous lines, and the probable past extension of Schoharie Creek in dotted lines.

The sharp turn in Plattekill Creek, southeast of Plaat Clove P.O., has been called an "elbow of capture." Find others. How do these elbows of capture show the fact that the divide between the east- and west-flowing streams has migrated, and the direction of its migration? Illustrate your answer.

REFERENCE. — Tarr's "Physical Geography of New York State," pp. 190, 191.

PART II. *Buckhannon Quadrangle, West Virginia.* — In what part of the state is this quadrangle located? Into what does the Buckhannon River empty?

West of the town of Buckhannon, locate and trace Brush Fork, Spruce Fork, Glady Fork, Right Fork of Stone Coal Creek, Pigeon Roost Fork, West Fork (Monongahela River).

Make a sketch map of all except the last. The Right Fork of Stone Coal Creek is tributary to the West Fork of the Monongahela River. How do the tributaries of the Right Fork indicate the direction of flow? How do Spruce Creek and Glady Fork agree in this respect with the rest of the tributaries?

Does Brush Creek valley notably widen or narrow

from the mouth upstream? Is this the usual behavior? How high is the divide at the head of Brush Creek? Trace the divide between the West Fork (Monongahela River) and the Buckhannon. Is it midway between the streams? Which stream would you infer is most actively eroding? The Buckhannon in this region is nearly graded, while the West Fork is in a younger stage of activity. Taking into consideration the activities of West Fork and of Buckhannon rivers, the tributary directions, the valley of Brush Creek, and the divide at the head of Brush Creek, work out the history of Brush Creek. Illustrate with maps, showing present and former conditions. There are other examples in this region. What is the probable fate of the upper Buckhannon?

REFERENCE. — Buckhannon Folio, West Virginia, U.S.G.S.

65. YOUTHFUL TOPOGRAPHY AND DRAINAGE

*PART I. *Fargo Quadrangle, North Dakota–Minnesota.* — In what part of the state is this region? How far, and in what direction, is it from Milwaukee? What is the general character of the topography? What is the contour interval? Draw a profile along the parallel of 46° 50′. What kind of divides, flat or sharp? How would you describe the valleys as to depth, width, and steepness of valley sides? Is the drainage well organized; *i.e.* is the country well drained? Are there

many tributaries? What is the length of the Red River, not taking into account the meanders? What is its length including the meanders? (To measure this, take a piece of fuse wire or a stiff string and lay it along the river. Then measure. Let one student measure in the first four squares, another in the second, etc. Then the sum of the measurements will be the length of the river.)

What is the fall or slope of the Red River? If you cannot get the exact figures, how close can you determine it? Does the country slope in the same directions as the rivers flow? What relation does the meandering of the river have to these questions? This region is a part of the bed of Lake Agassiz which once covered the Red River Valley. Why can the roads run so straight? Do you think that the region has long been subject to erosion? Why?

REFERENCES. — Fargo Folio, U.S.G.S.; The general region is described in Monograph 25, U.S.G.S.; "The Glacial Lake Agassiz," by Warren Upham.

*PART II. *Eagle Quadrangle, Wisconsin.* — In what part of the state? Is the run-off good? Do the streams have steep or gentle slopes? Do you think they are rapid or sluggish? Are the tributaries well developed? Are the divides distinct or indistinct? Is the region dissected? What proportion of the country is swampy? What proportion is covered with lakes? Do all the

lakes have an outlet? Are there any undrained depressions? What stage of erosion does the country belong to? Will the lakes probably become larger or smaller? How? Will the swamps increase or decrease in area? How? Will the divides become more or less distinct? How? During the glacial period the continental glacier obliterated the preglacial topography and left the present surface.

REFERENCE. — Professional Paper No. 34, U.S.G.S., by William C. Alden. Plates and illustrations.

PART III. *Highwood Quadrangle, Illinois.* — How far, and in what direction, is this region from Chicago? Compare the divides with those in the Fargo and Eagle quadrangles. Compare also the organization of the streams. Compare the run-off. Compare the streams in the belt east of the Chicago and Northwestern Railroad with those of the rest of the quadrangle. Compare the stream valleys. Which streams and valleys are the older in years? Which are older in *development* or *stage* of *erosion?*

All of these quadrangles illustrate regions in the youthful stage of erosion. Enumerate carefully their characteristics of this stage. Some are farther advanced toward maturity than others. Note and describe these various stages of youthful topography and drainage.

Supplementary. — Into what does the Desplaines River flow? What is its slope per mile? What is the

slope per mile of the streams flowing into Lake Michigan? Which set of streams best show *headwater* erosion? Why?

REFERENCE. — Professional Paper No. 34, U.S.G.S., by William C. Alden, Plate III.

PART IV. Youthful Topography and Drainage in Soluble Rock (mostly limestone). *Arredono Quadrangle, Florida.* — In what part of the state is this region? What is the contour interval? What is the general altitude? How would you describe the surface — as level, rolling, or rough? How does it compare with the Fargo, N.D., region? Is the drainage well organized? Compare with the Eagle, Wis., region. Have all of the lakes outlets? Inlets? In a region of soluble rocks the streams often disappear and flow underground. Note the "sink" into which Hogtown Creek flows. Find other examples. These subterranean streams often reappear. Find an illustration on Hatchett Creek. (See Blue Spring and Wekiwa River. *Dunnelon Quadrangle, Florida.*) Could the absence of outlets of many of the lakes be accounted for by the rainfall of the region? How? What is the rainfall of Florida? Does this reason hold for these lakes? Find sink holes. What is their origin?

Compare the stage of erosion of this region with the other regions taken up in this exercise. Which of the four regions are advanced in youth? Which are less

advanced? From the drainage, how would you infer the solubility of the rocks?

*PART V. *Youthful River, Niagara Falls Quadrangle, New York.*— How far below the general level of the country is the Niagara River above the falls? Below the falls? How would you classify each part of the river as to stage (youth, maturity, or age) in the cycle of erosion? Of what stage are the falls a characteristic?

66. MATURE RIVERS AND VALLEYS

*PART I. *Pittsburg Quadrangle, Pennsylvania.*— How do the rivers shown here differ from youthful and old rivers in the kind of work they are evidently doing? Is the Monongahela degrading or aggrading or at grade? How wide a valley has it cut? Is it cutting at all places? Is it building at all places? Where is it cutting? Where building? Are the main rivers corrading vertically? Laterally (lateral planation)? In general, do the streams show lateral corrasion in the straight reaches or the bends? Find and sketch a good example. (Sketch with contour lines.) Is the lateral corrasion greatest on the outside or the inside of a bend? Why? Are flood plains forming? About what is their average width? Are they forming in the straight reaches or the bends of the river? On the outside or the inside of the bends? On the downstream or the upstream sides of the spurs? Sketch a good example.

How wide are the river valleys? How deep? Make a cross section across the Monongahela Valley from New England to Portvue. Are the slopes from the divides to the river equal? What are the slopes per mile from the divides to the river? How do these slopes compare with those of the Red River on the Fargo, N.D., Quadrangle? With the streams tributary to Lake Michigan in the Highwood, Ill., Quadrangle? Which valleys are *V*-shaped? Which *U*-shaped?

What large city is shown in this quadrangle? Note the Carnegie Quadrangle to the west. What river factors have determined the location of this city?

PART II. Early Mature and Young Valleys. *Elmira Quadrangle, New York–Pennsylvania.* — What is the general height of the upland? Of the lowlands? How wide is the valley of Chemung River from Hawes Hill to Elmira? How wide is the valley running through Big Flats, Horseheads, and Elmira? The latter valley was formerly occupied by the Chemung River, and this river has been forced by an ice blockade to cut its present valley. What is the general slope of the valley sides of the present Chemung Valley? Of the former valley? How do the width of valley and slopes of valley sides of the abandoned valley compare with the same features of the present valley? Which valley has the most tributary valleys per mile? How is this to be explained? Do you think that the present Chemung

River cut its entire valley or found some of its valley already cut? What explanation does the course of Hendy Creek offer? Does this explanation account for the widening of the Chemung Valley west of Elmira? How high would the Chemung River have to rise in order to occupy its old valley? Have Singsing and Newtown creeks always had their present lengths? Is there any probable relation between the delta at the mouth of Seely Creek and the straight course of the Chemung River across Elmira?

*67. EARLY MATURE TOPOGRAPHY

Marshall Quadrangle, Arkansas.—In what part of the state is this region located? Into what does the Buffalo Fork empty? What is the average elevation of this region? What is the average depth of valleys? (Buffalo Fork, Middle Fork of Little Red River, East and Middle Fork, Illinois Bayou, South Fork of Little Red River.) What is the slope per mile of Buffalo Fork below Wolem? Of Middle Fork Little Red River from Boston Mountains to the edge of the map? What is the general width of the divides in the northern third of the region? The middle third? The southern third? In general, are the divides flat-topped or sloping? How does the steepness of the valley sides compare with those in the Pittsburg region? Is lateral corrasion (lateral planation) prominent in any of the streams?

In all of the streams? Sketch a good type divide. In general, do the roads follow the divides or the valleys? Why?

Are the tributaries well developed? Is the country well drained? Is the run-off good? Compare the organization of the drainage with the Fargo, N.D., and the Eagle, Wis., regions. Are the divides broadest and flattest near or far from the main streams? Why?

*68. MATURE TOPOGRAPHY AND DRAINAGE

Waynesburg Quadrangle, Pennsylvania; Pittsburg Quadrangle, Pennsylvania. — Compare these quadrangles with the Marshall, Ark., Quadrangle as to: width of divides, steepness of slopes, dissection, organization of streams, run-off, slope of streams, formation of flood plains, lateral corrasion.

Which represents a region in early maturity? Late maturity? Sketch a region three miles or more square, showing a region in early maturity and one in later maturity.

Is a mature region valuable for agricultural purposes? Is it densely populated as a rule? Account for Pittsburg and its neighboring cities. Have the sudden floods to which the Monongahela and the Ohio are subjected any relation to the maturity of topography in their basins? What?

REFERENCE. — The Waynesburg Folio, U.S.G.S.

69. A REGION IN OLD AGE

Caldwell, Kan., Quadrangle. — In general, how would you describe the relief of this region — strong or weak? Are the divides broad or narrow, flat- or steep-sided? Are the valleys wide or narrow? Deep or shallow? Steep-sided or sloping-sided? Are there many or few tributaries? Is the drainage well or poorly organized? Are the stream slopes steep or gentle? Taking these features all together, what stage do they indicate? The streams have a steeper gradient than would be likely in age, but the other features are consistent. It is seldom that we can find an area of this size where all the features are consistent with any one stage in the cycle. Sketch the most typical one, four inches square, that you can find. Is the region, as a whole, in early or late age? Which are most typical, the larger or smaller streams? How would you distinguish this from youthful topography?

70. A STREAM IN OLD AGE

Abilene Quadrangle, Kansas. — The Smoky Hill River has many of the features of age. What is its depth below the general level of the country? How would you describe the course of the river? From its slopes, would you infer that the current is strong or weak? Are the valley sides steep? How would you expect them to be in this case?

71. A REGION IN OLD AGE, RECENTLY REVIVED

Marietta Quadrangle, Georgia. — This region was worn down to a nearly featureless plain (peneplain), and then the streams were rejuvenated. The rejuvenation is so recent that the main features of aged topography still remain.

In what part of the state is this region? How far and in what direction from Atlanta? Into what does the Chattahoochee River flow? What is the general altitude? How far are the main streams below this altitude? How far are the minor streams?

Compare the divides with those of the Fargo, N.D., region. How are they similar? Is the drainage well organized? Sketch the streams of a region three miles square south of Dallas. South of Fargo, N.D. (Fargo Quadrangle), and south of Waynesburg, Pa. (Waynesburg Quadrangle). Do these regions compare in the matter of stream organization? In the steepness of slopes? In general dissection?

*72. REVIEW. THE CYCLE OF EROSION

Chester Quadrangle, Pennsylvania–Delaware–New Jersey. — Compare the country on opposite sides of the Delaware River as to general altitude, dissection, depth and side slopes of valleys, stream slopes and tributaries, organization of drainage, divides, their width and slopes.

In what stage of erosion is each region?

*73. A PENEPLAIN RECENTLY ELEVATED

Marietta Quadrangle, Georgia. — This area has been nearly peneplained and then elevated. What is the average elevation? Imagine yourself looking south from Lost Mountain. What kind of a sky line would be presented, smooth or rugged? In what stage of erosion is most of the country? What change does the topography show in the stage of erosion as you pass away from the main drainage lines? Does it become more or less youthful? How is this in a youthful topography? In a mature topography? How far below the general surface is the Chattahoochee River? Kenesaw Mountain is a monadnock. How high is the main mountain above sea level? Above the general level? Find several other monadnocks. Are they near the main drainage lines? Why? Do the roads and railroads in general follow the valleys or the divides?

REFERENCE. — The general region is described in the paper on the southern Appalachians, by C. W. Hayes, in the "Physiography of the United States." This region is briefly described on page 326.

74. A REJUVENATED OR REVIVED RIVER

Guyandot Quadrangle, West Virginia–Ohio. — At a previous period in its history the Guyandot River was compelled to aggrade its channel. The old valley is

filled with silt, sand and gravel scores of feet deep. The cause for this is thought to be a glacial obstruction near the mouth of the valley, which caused aggradation there, and this aggradation caused in turn the gradation upstream. Why? Later the obstruction was removed, and the stream was rejuvenated. Why? Where would such a rejuvenation begin — near the mouth, all along the course, or near the head of the stream? How would it differ from the rejuvenation caused by an uplift with tilting?

How wide is the valley of the Guyandot at the top? At the bottom? How deep is the old valley? How deeply into the bottom of this valley is the channel of the river cut? Make a profile across the valley about two miles above Guyandot. What part of the valley has mature slopes? What youthful? Do you find similar evidences of rejuvenation along Twelvepole Creek? At what places along the Guyandot do you find cliffs? Are they by straight reaches or meanders? Why?

Terraces. — Make a profile across the Ohio Valley near Labelle or near Huntington. How high are the terraces above the river? Are their surfaces level or sloping? How far beneath the uplands are they?

REFERENCE. — This region is described in Professional Paper No. 13, U.S.G.S., by W. G. Tight.

75. INCISED MEANDERS (ENTRENCHED MEANDERS)

Huntington Quadrangle, Pennsylvania. — In what part of the state is this region? How far, and in what direction, from Philadelphia? From Pittsburg? Locate the Juniata River. Into what does it flow? The Raystown Branch of the Juniata River flows between two ridges of hard rock. How high are they? How far below the crests of the ridges is the stream in the southern part of the map? In the northern part? What is the height above sea level of the stream near Hawn Bridge? Near Entriken Bridge? What is the total fall of the stream between the two places? What is the average fall per mile *along* the stream? In a "*bee line*"?

Do you think the stream is aggrading, degrading, or at grade? Why? Do streams usually meander or aggrade with the fall of the Raystown Branch? This stream is thought to have reached a meandering course and then have been revived or rejuvenated. After rejuvenation, the stream acquired a new energy and began to corrade, but still was obliged to keep the meandering course which was appropriate to a stream of low slope. Looking at the spurs between the meanders, are their slopes equal? Which is the steeper, the upstream or the downstream slope? What is the reason for this? At one time the stream flowed along the 700-foot con-

tour. Has it since corraded vertically? Laterally? How far vertically? How far laterally?

Copy the two meanders just below Fink Bridge. Draw a dotted line to represent the probable stream course along the 800-foot contour. How far has the stream moved laterally? Has the meander also moved downstream? What makes you think so? Make a profile across the spur below Entriken Bridge, and explain the slopes. How could you infer the direction of the stream from the spurs alone? In what stage of dissection is this region? Do you think the rocks lie horizontal or tilted?

76. A SUPERIMPOSED STREAM

Germantown and Norristown Quadrangles, Pennsylvania.—Trace the Wissahickon Creek (Germantown Quadrangle). Compare the width of valley and steepness of valley sides in the upper and lower portions. What is the general elevation of the country in which the gorge is cut? In which the upper portion lies? Is there any easier course for the Wissahickon to reach the Schuylkill? In what kind of rock is the gorge cut (Figure 14)? The upper part of the valley? Which rock is least resistant to erosion? How does this show in different parts of the valley? What explanation can be offered for the course of the Wissahickon?

Harrisburg and New Bloomfield Quadrangles, Pennsylvania.—Note the course of the Susquehanna River.

Does the river take the easiest course? Why? Did it develop its course on the *present* topography? Why? When the river first started, did it begin its course on this topography or on a plain? Which way must this plain have sloped at that time? What other streams in these quadrangles are evidently superimposed?

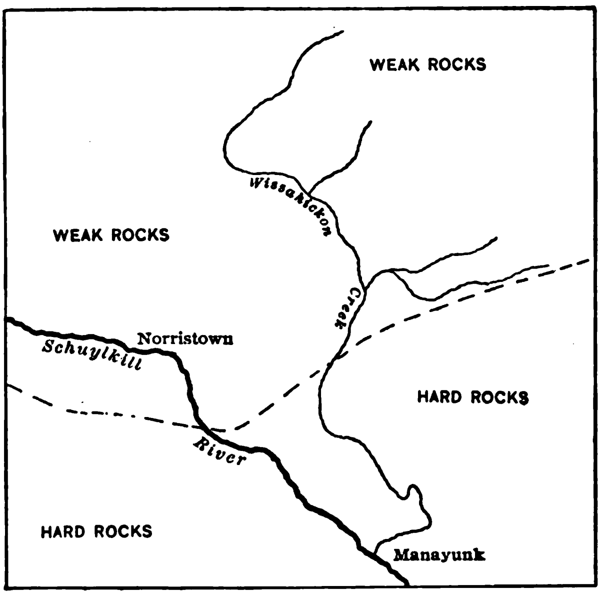


FIG. 14.

*77. DROWNED STREAM VALLEYS

Hampton Quadrangle, Virginia. — In what part of Virginia is the quadrangle located? How far, and in what direction, from Norfolk? Locate Hampton, Fort

Monroe, Old Point Comfort. Is the coast smooth or indented? On any good map, compare this coast in this respect with the coast of Florida, California, Massachusetts. What is the length, width at mouth, and fall per mile of Cheesman Creek, Poquoson River, Back River, and Hampton Creek? Do these streams differ in any respect from those you have been studying? Is it likely that these streams have the velocity or volume to erode such wide mouths? If the coast has sunk, how would these valleys be explained? How do the Goodwin Islands indicate a sinking of this coast? If the coast were to rise, how would it change the appearance of the larger streams and valleys? Sketch the streams as they would then appear. Compare this coast with a good map of Chesapeake Bay. What similar features?

78. FIELD STUDY OF CONSEQUENT, INSEQUENT AND SUBSEQUENT STREAMS

On a newly made lawn or other fresh surface, what determines the course of the streams? Streams whose courses are determined by slope alone are called *consequent* streams. Compare a valley that is just starting with one that is older. Which is longer? Deeper? Wider? Give at least four reasons for each answer. How do the streams lengthen themselves? Are the valleys deepest at head or mouth? Widest? Give all the reasons you can. Sketch each stream, showing the

tributaries. Do the tributaries have any definite arrangement? Do they divide and subdivide like the branches of a tree? Streams which branch and sub-branch without any definite guidance by rock structure are termed *insequent.* Their valley pattern is termed *dendritic* (treelike).

Observe the streams developing on a plowed field or any other surface with a similar structure. Do the streams, as a whole, develop *across* or *along* the furrows? Why? Streams whose courses are largely guided by rock structure are called *subsequent.*

79. MAP STUDY OF CONSEQUENT, INSEQUENT, AND SUBSEQUENT STREAMS AND THEIR ASSOCIATED VALLEY PATTERNS

Hampton Quadrangle, Virginia. — This region was formerly covered by water, but has in recent geological times been exposed. Upon this new surface of soft materials the streams took their course. What factor determined their direction? Which way do the main streams flow? Would you say that the tributaries to the main streams are also consequent? Sketch a good type consequent stream. (In the case of surfaces long exposed to erosion it is often very difficult to determine whether a stream is consequent or not.)

Harrisburg Quadrangle, Pa. — Paxton Creek (northeast of Harrisburg) is flowing on fairly homogeneous

rock. Streams like Fishing Creek north of Blue Mountain, are flowing on rock with a structure shown in Figure 24. What kind of rock makes Fishing Creek Valley? Blue Mountain? Second Mountain? What is the arrangement of the rocks, irregular or in bands? Which stream, Paxton Creek or Fishing Creek, seems to follow rock structure? What term should be applied to these streams? Are the tributaries to Fishing Creek insequent or subsequent streams? Sketch good examples of insequent and subsequent streams.

Stream and Valley Patterns.—Streams and valleys like those of Fishing, Stony, and Clark Creeks are said to have a parallel or "trellis" pattern. Those like Paxton Creek are said to have a dendritic (treelike) pattern. How are these terms significant? Sketch good examples of both patterns, not using the examples already named.

Longitudinal and Transverse Valleys.—What valleys are parallel with the ridges? What valleys cut across the ridges? Which valleys are longitudinal (lengthwise) with respect to the ridges? Which transverse (crosswise) with respect to the ridges? What influences have these valleys on the direction of roads? Which valleys give access *into* the ridge belt? Which, *along* the ridges? What is the best example of a transverse valley shown on this quadrangle?

*80. STUDY OF A CAÑON

Bright Angel Quadrangle, Arizona. — In what part of Arizona is the quadrangle located? How far from the mouth of the river? What is the general altitude of the upland? How far below the upland is the Colorado River? Has it rapids? Is the river a graded stream? How wide is the cañon from Kaibab Plateau to Coconino Plateau? Make a profile across the cañon from Grand Cañon station northward, using 250-foot contour intervals. Where are slopes steepest? Most gradual? The cañon is cut in two kinds of rock, crystalline and approximately horizontal sedimentary rocks. Can you determine these rocks from the steepness of the slopes, the evenness of the slopes, and the width of the cañon cut in them? How wide is the granite gorge compared with the cañon that is cut in sedimentary rocks? Which is the younger in stage of erosion, the inner or the outer gorge? Which, in years? Would the relative ages of these gorges have anything to do with their steepness and width? Why do the sedimentary rocks form the alternating steep cliffs and gentler slopes?

How many tributaries has the Colorado River? Do they all have steady streams? How far from the river has headwater erosion proceeded? Compare in this respect and in slopes with the region adjacent to the

Niagara and Ohio rivers. How would climate affect these factors?

What is a spur? Dana Butte is a good one. Find other examples. Are most of the spurs in this region smooth or rough in their horizontal outline? Keep them in mind, and compare with spurs of more humid regions. Are the spurs, in general, highest at the point (end) or at the base? Why? Are the streams numerous or few? As a whole, are they steady or intermittent? How long is the longest stream on the quadrangle? Are the springs and wells usually mapped? Why are they on this quadrangle? What evidences as to rainfall do you find?

Many photographs of the Grand Cañon are taken from points on this quadrangle. Locate all you can, including the place from which they were taken and the area included in the photograph.

*81. STUDY OF A WATERFALL

Niagara Falls Quadrangle, New York.—How high is Niagara Falls? How high is the crest above sea level? What shape has the crest of the Horseshoe Falls? Why has it this shape? (The resistance of the rock is practically equal across the crest.) Has the crest of the American Falls the same shape? Why? How wide is the crest of the Horseshoe Falls?

The rapids extend from approximately the north end

of Goat Island to the crest of the falls. How long are the rapids? What fall have they? How many feet to the mile do they fall? How wide is the valley above the falls? How deep? How wide and deep below the falls? How would you account for the contrast between the valley and the gorge?

How long is the gorge? Make a section about a mile above the whirlpool. Is the gorge section box-

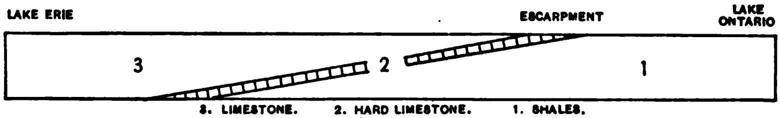


FIG. 15.

like or flaring at top? Why is it so? Is it young, mature, or old?

What change in the direction of the gorge at the whirlpool? How far has the river worn into the Bowman Creek Valley. (There is an old drift-filled valley at this point.) Why should the water move here so as to make the whirlpool? What is the fall of the river from the foot of the falls to Lake Ontario? How much does it fall per mile? Is the river valley youthful, above the falls? Below the falls? At what stage in the cycle of erosion is the surrounding country?

The structure of the rocks at the falls is shown in Figure 15. The Lockport (hard) limestone is harder

than the underlying shales and limestones. How does the rock structure account for the falls? If the rock were homogeneous, how would the falls differ from their present form? Which way do the rocks dip? Will the falls become higher or lower as they recede?

CHAPTER IX

LAND FORMS IN VARIOUS ROCK STRUCTURES — STRATIFIED AND HOMOGENEOUS ROCKS

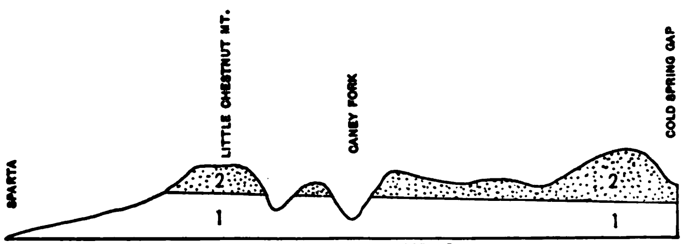
*82. HILLS AND VALLEYS IN STRATIFIED ROCKS OF VARYING STRENGTH AND IN HOMOGENEOUS ROCK

Pikeville Quadrangle, Tennessee. — The general structure of the region northwest of the Sequatchie Valley is shown in the generalized section, Figure 16. Which rock, the sandstone or the limestone, will ordinarily be most resistant to erosion? What kind of depressions do you find in the northwest part of the quadrangle? What kind of rock, sandstone or limestone, do these indicate?

Note the slopes of Little Chestnut Mountain and Milksick Mountain (northwestern part of quadrangle). Make a north-south profile across each. How do their slopes contrast? One is capped with the sandstone and the other is not. Which one has the sandstone capping? How do you know? Welch Knob has the same structure as Little Chestnut Mountain. How do its slopes contrast with those of Potts Knob, Burns Knob, and the hills to the east of them? The hills east of Welsh Knob are cut in sandstone. Make a generalized statement as to the shape of hills cut in homogeneous rock and those in

rock of varying resistance. Illustrate your statement with sketches of good types.

Note how the valley of Caney Fork widens in passing from the structure shown in Figure 16 to the limestone. About where is the change in rock? Where are steepest valley slopes? Why? Note where Cane Creek and Glade Creek cut through the overlying



2. SANDSTONE. 1. LIMESTONE.

FIG. 16.

sandstone into the limestone. Explain the sudden change in the valley section. Pilot Falls marks the place where the underlying limestone is reached on West Fork. Why should there be falls there?

83. MOUNTAINS OF CIRCUMEROSION (CIRCUMDENUDATION)

**Kaaterskill Quadrangle, New York.* — Note the well-marked chain of peaks and another chain, parallel to the first, not so continuous. Note the heights of Plattekill Mountain, Indian Head, Twin Mountain, Sugar Loaf Mountain, Plateau Mountain, Hunter Mountain. Are

they uniform? Do they increase or decrease in height in any direction? Note, also, the heights in the range including North Mountain, Stoppel Point, Onteora Mountain, Parker Mountain, and East Jewett Range. The rock from which these ranges are formed is nearly horizontal and mostly sandstone. Since the mountains are not caused by differences in rock structure, what agents have produced them? Account for the group including High Peak and Roundtop Mountain and Clum Hill. Do their heights increase or decrease in any direction? Why should they? Do the peaks show any relation to the tributaries of the streams?

84. MOUNTAINS IN LATE YOUTH (CIRCUMEROSION)

Marshall Quadrangle, Arkansas.—How far, and in what direction, from St. Louis? How high above sea level are the Boston Mountains? How high are they above the general level of the valley bottoms? Are the summits flat or sloping?

The rock is largely horizontal and stratified. The Boston Mountains are a dissected plateau. Is it more or less dissected as you approach the White River? Why? Why is Granny Mountain separated from Cherry Flat? What is the evident origin of the range ending in Point Peter? How will this range change with continuous erosion? How will the Boston Mountains change provided there is no interruption to the cycle?

85. MOUNTAINS OF CIRCUMEROSION IN MATURITY

Charleston, West Virginia. — In what part of the state is this region? How do the scale and contour interval compare with that of the Marshall, Ark., Quadrangle? The general region here is known locally as the "Mountains." Both the Marshall and Charleston regions are dissected plateaus with nearly horizontal stratified underlying rock. Compare the two areas as to residual uplands and depth of valleys. Sketch Boston Mountains and the three knobs, Grapevine, Hughes, and Sugar Camp (Charleston Quadrangle).

*86. ESCARPMENTS

Niagara Falls Quadrangle, New York. — What is an escarpment? How distinguished from a cliff? A hill? How high is the Niagara escarpment? What is its average slope per mile? What is its structure (see Figure 15)? What kind of rock, and what location of this rock makes the escarpment? If the rock underlying this area were uniform in resistance to weathering with the rock above, how would the form of the escarpment probably differ from the present form?

REFERENCES. — The chapter on Niagara Falls, by G. K. Gilbert, in "The Physiography of the United States," 1896; "The Physical Geography of New York State," Chapter IX, by R. S. Tarr, 1902.

87. ESCARPMENT AND OUTLIERS

McMinnville Quadrangle, Tennessee. — In what part of the state is this region? What two areas each of about equal altitude? What is the average altitude of the higher area? What is this area called? What is the average altitude of the lower area? What is the average difference in altitude between the two areas? Is the slope between them more or less than that of the Niagara escarpment? What is the slope per mile through Thaxton (southwestern part of the quadrangle)?

What is the structure of the area (see Figure 17)? What rocks make the highland? The lowland? How

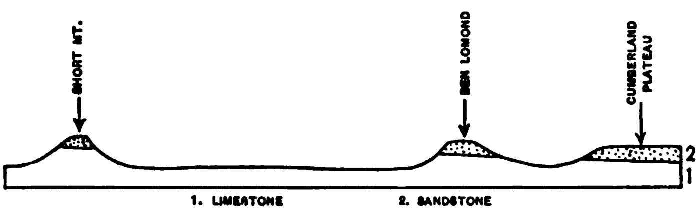


FIG. 17.

is the structure similar to the Niagara region? How different? How is the escarpment made in each case? The line of hills, including Butterson Knob, Ben Lomond, Mount Cardwell, Turkey Cock, and the unnamed hill east of Frank Ferry on the Caney Fork, were formerly part of the plateau. Such are called *outliers*. Does this line of hills run straight or does it bend to the east? Does

the better development of drainage in the region of Falls City suggest an explanation of the swerving of the line of hills? Short Mountain is an outlier, capped with the same kind of sandstone as the plateau. What does this indicate as to the former extent of the Cumberland Plateau? Some of the following hills are overlaid with sandstone, and some are not. Judging by their height and slopes, which of the following hills are overlaid with sandstone and which are not? Ben Lomond, Short Mountain, Little Cardwell, Turkey Cock, Cope Mountain. Verify your conclusion from the geological map in the McMinnville Folio.

REFERENCE. — McMinnville Folio, Tennessee, U.S.G.S.

88. A MATURELY DISSECTED MOUNTAINOUS DIVIDE

PART I. *Mount Mitchell Quadrangle, North Carolina–Tennessee.* — In what part of North Carolina is this region? How far, and in what direction, is it from Charleston, S.C.? How many ranges of mountains are there? Is Mount Mitchell an isolated peak or a part of a range? The rocks of this region are largely crystalline and not very different in resistance to erosion. The land forms, therefore, are largely due to erosion and not to rock structure. What is the evident origin of Black Mountains? Is its crest even? Straight? Compare with Blue Mountain on the Harrisburg, Pa., Quadrangle. (Blue Mountain is due to erosion on folded rocks. It is

a tilted bed of sandstone with softer rocks on either side.) How do the Black Mountains compare with Blue Mountain in straightness of course and evenness of crest?

Is there any parallelism of ridges in the Mount Mitchell region such as you find in the Harrisburg region? Are the different peaks in the Mount Mitchell region at the head of streams or between streams? How would you explain your answer? How would you account for the sudden change in the direction of the Blue Ridge at Rocky Mountain? Note the various gaps. What relation have they to streams? (Are they between the headwaters of streams or in the line of opposite-flowing streams?) How would you explain your answer? Trace the Blue Ridge. What is its general altitude? Do the ranges change with the changes in direction of streams on either side? Do you think that the ranges determined the stream courses, or that the streams determined the direction of the ranges? What are your reasons? Compare the Blue Ridge with the Catskill Mountains (Kaaterskill Quadrangle, New York). Which are oldest in their development? As erosion proceeds, do you think the Blue Ridge will resemble East Jewett Range or *vice versa?* Sketch a good example of a mountainous divide.

REFERENCES. — Mount Mitchell Folio, North Carolina-Tennessee. The chapter by C. W. Hayes on the Southern Appalachians in the "Physiography of the United States."

PART II. *Ishawooa Quadrangle, Wyoming.* — In what part of Wyoming is this region? Into what river does the Shoshone River flow? The Yellowstone? Where do their waters finally reach the sea? What is the height of the Absaroka Range? Average width? Is it a fairly single ridge, or does it have spurs? Is it a straight ridge? What is the evident origin of these spurs? What is the height of the crest of Sheep Mesa, Wapiti Ridge, Ishawooa Mesa, Needle Mountain, Thorofare Plateau, Trident Plateau? How do these compare in elevation with Absaroka Range? The rock of all, except the northeast corner of the region, is crystalline and not notably more resistant in one place than another. What is the evident origin of the range? Why is its crest so crooked? What is the origin of its spurs (*e.g.* Wapiti Ridge)? The region is a dissected plateau. How far, in general, have the streams cut their valleys into this plateau? What remnants are left? Ice erosion has aided in narrowing this ridge. The amphitheater-like heads of valleys (cirques), such as that at the head of Cabin Creek, are due to ice erosion.

REFERENCE. — Absaroka Folio, Wyoming, U.S.G.S.

CHAPTER X

LAND FORMS AND ASSOCIATED PHENOMENA IN FOLDED AND TILTED ROCKS

*89. YOUNG ANTICLINAL MOUNTAIN AND SYNCLINAL VALLEYS

Ellensburg Quadrangle, Washington. — What is the general slope of the elevations, hills, or ridges? What general direction? How high are the ridges above sea level? Above the valley bottoms?

The rock of the region is a basalt. Referring to the structure section (Figure 18), how are the rocks ar-

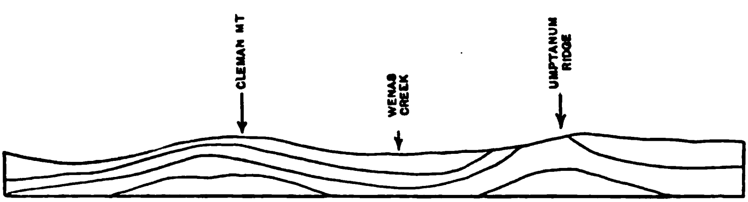


FIG. 18.

ranged? With what structures do the ridges correspond? The valleys? Do you think the region has been much eroded? Are the streams consequent? Why? (Exercises 78 and 79.)

REFERENCE. — Ellensburg Folio, Washington, U.S.G.S.

90. AN ANTICLINAL MOUNTAIN (UNSYMMETRICALLY FOLDED)

Frostburg Quadrangle, Maryland–West Virginia–Pennsylvania. — Make a profile across Wills Mountain from Roberts westward, using the 100-foot contours. Are the slopes equal? What is the eastern slope per mile? The western? What makes the mountain (see structure section, Figure 19)? What makes the valleys

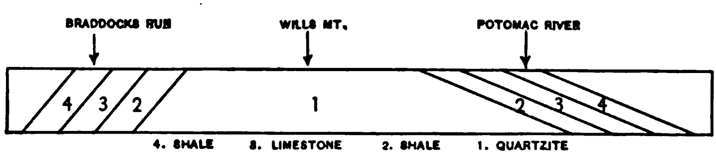


FIG. 19.

on either side? How high is Wills Mountain? Would an unsymmetrically folded anticline have unequal slopes before it was eroded? Would it after erosion? Does the folding in this mountain agree with the slopes? Could the slopes be due to unequal erosion on either side by the Potomac and by Braddock Run? Which of these streams has the largest volume? The greatest fall per mile? Which has eroded the more? If the slopes on Wills Mountain are due to the erosion of these two streams, would they be as they are at present, or would they be reversed? (It would be unsafe to generalize by saying that all ridges with unequal

slopes are due to unsymmetrical folding. Many other factors may produce a lack of symmetry in slopes.)

91. AN ANTICLINAL VALLEY

Pikeville and Kingston Quadrangles, Tennessee.—How long is the Sequatchie Valley? How wide? How deep? Is it variable in width? How does it compare with most valleys in this respect? How does it compare with most valleys in straightness? What is the rock structure underlying the valley as shown in the generalized section, Figure 20?

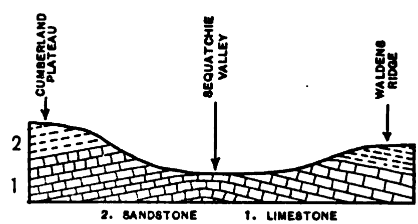


Fig. 20.

Would the sandstone or limestone erode more rapidly? In such a structure, what kind of forms would result from erosion? Make a profile across the valley. Where are its steep slopes? Why would a flat-bottomed valley with steep sides result from such a structure? At what stages would a river working in a homogeneous rock have such a valley section? On the west side of the valley, do you find any topographic evidence of the limestone? What kind of a river is the Sequatchie, insequent or subsequent (Exercises 78 and 79)? What features are utilized by the roads out of the valley?

Kingston Quadrangle. — Where does the Sequatchie River end? Grassy Cove has about the same structure as the Sequatchie Valley. It is a sink hole on a large scale, whose waters flow underground into the Sequatchie. About how many square miles are included in Grassy Cove? How does the section across Black Mountain differ from that across the Sequatchie Valley? Which part of the anticline is in the later stage of erosion? What reasons for the difference in stage? The structure of the Crab Orchard Mountains is the same as that of Black Mountain. So far as structure is concerned, what name could you apply to them? What other examples? What is the probable ultimate fate of Crab Orchard Mountains? Are they, as a group, in youthful, mature, or old stage?

REFERENCE. — Kingston Folio and Pikeville Folio, Tennessee, U.S.G.S.

*92. AN ERODED ANTICLINE WITH MONOCLINAL RIDGES

Grantsville Quadrangle, Maryland-Pennsylvania. — Make a profile from the letter *V* in the word *Savage* (Big Savage Mountain) to the letter *L* in the word *Salt* (Salt Block Mountain).

Note the geological section, Figure 21. What rocks are hardest? What soft? What does the dip of the rocks show the structure to be, horizontal strata, anticline, or syncline? What formations make the ridges?

What, the valleys? Place beneath your profile the symbols for the various rocks, as in Figure 21. (Use dots for the sandstones, short straight lines for the shales, and small circles for the conglomerates.) Which of the formations make two opposite ridges? How can they do this? Would two opposite ridges be made if the anticline were not eroded? Why? Are

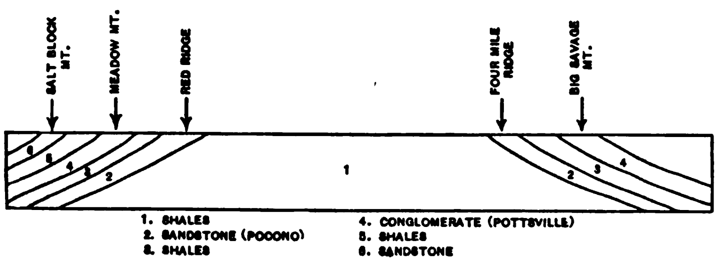


FIG. 21.

the slopes of the ridges equal? If not equal, which slope, in general, is steepest? Which the more gradual? The slopes of Four Mile Ridge have not the same arrangement as those of the other ridges. Can the work of Savage River have an effect here which is not felt in the case of the other ridges? Ridges whose *rocks* have a notably steep dip in one direction are termed *monoclinal ridges*. What are the monoclinal ridges in this region? You will notice that the shales between the two monoclinal ridges, Four Mile, Elbow Ridge, and Red Ridges, are divided into ridges at approximately

right angles to the general trend of the anticline. Can they be best explained by the structure of the rock, or the erosion of the streams? How do they compare with monoclinal ridges as to arrangement of slopes, continuity, regularity of outline, smoothness of crests? What have you had of similar origin? The Pottsville conglomerate and Pocono sandstone form many of the Appalachian ridges.

93. SYNCLINAL MOUNTAINS

Staunton Quadrangle, Virginia–West Virginia. — The line of elevations, including Great North Mountain, Crawford Mountain, Lookout Mountain, Narrow Back Mountain, have the same structure (see Figure 22). What is their structure? The Pocono sandstone has been eroded from most of the syncline, except in a few patches, which form the mountains named above. Why should the sandstone form the mountains?

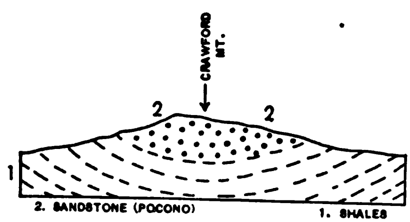


FIG. 22.

Pawpaw Quadrangle, Maryland–West Virginia–Pennsylvania. — Trace Town Hill. What is its length? Average height? Is the crest flat or sloping? Is it more or less flat near Fifteen Mile Creek and Crooked Run? Why? What is the structure of Town Hill (see

Figure 23)? What rock caps the ridge? What underlies it? What makes the ridge flat-topped? On Town Hill, about one mile southwest of Fifteen Mile Creek and two miles northwest of this creek, the overlying Pocono sandstone has been removed by erosion. What effect has the absence of the sandstone on the crest of Town Hill? The crest of Town Hill has a sandy soil and the sides have a sandy loam. How would you account for these soils?

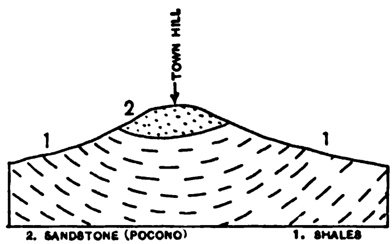


FIG. 23.

*94. ERODED SYNCLINES AND MONOCLINAL RIDGES

Harrisburg and New Bloomfield Quadrangles, Pennsylvania. — What are the prominent features of the region? Do they arise from horizontal or folded strata? What makes you think so? Trace Blue Mountain. How high is it? In the average, how wide is its crest? Is it highest near the Susquehanna River? Why? Trace Second Mountain. What is its name west of the Susquehanna River? Does it die out or turn back on itself? Trace it as far as you can, and note the different names that the same mountain bears. What is the average height of Blue Mountain, Second Mountain,

Third Mountain, and Peters Mountain? What is the structure of the ridges on the Harrisburg map (see Figure 24)? What three rocks make the ridges? What two of these have you noted before? Which one of the hard rocks makes Peters Mountain and Second Mountain? How can the one formation make the two ridges? What formation makes Third Mountain?

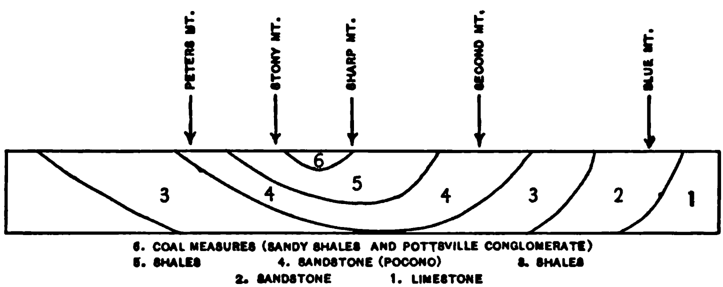


FIG. 24.

Classify Blue Mountain, Second Mountain, Third Mountain, and Peters Mountain, as to whether they are anticlinal, synclinal, or monoclinal ridges. The slopes of the ridges here are not so characteristic of their structure as they are on the Frostburg and Grantsville maps, owing largely to the thorough dissection by the streams. Why should this make a difference in characteristic slopes?

95. A SYNCLINE WITH PITCHING AXIS

Harrisburg and New Bloomfield Quadrangles, Pennsylvania. — You will note from the structure section that

Second Mountain and Peters Mountain are on opposite sides of a syncline, and that they meet in the New Bloomfield Quadrangle. Also, that Third Mountain comes to a point in the same direction. Before working out the reasons for this behavior, note Figure 25. It represents a syncline with the axis *xx* dipping towards the bottom of the page. That is, the syncline, as a whole, is higher above sea level at its north than at its south end. What would be the effect upon the distance between the outcrops of the hard layers *HH* (represented by the line *dd*) if the syncline were eroded down to the line *aa*? Would they be wider apart or nearer together? What would be the effect if the syncline were eroded to *bb*?

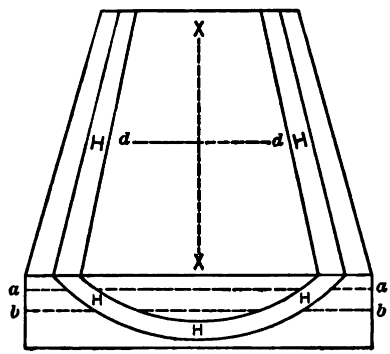


FIG. 25.

If the axis of the syncline were horizontal, the outcrops *HH* would be at equal distances apart. Why? As the syncline in Figure 25 is eroded, at which end will the outcrops *HH* approach each other most? At what end will they approach each other least? After long erosion the outcrops *HH* would have the position shown in Figure 26. Why? Make a general

rule for determining the pitch of a syncline by the way the outcrops approach each other. Illustrate, if possible, with block diagrams (like Figure 25) or by sketches.

With this principle in mind, determine the following questions: Why do Second and Peters mountains unite? Why do they point southwesterly? Which way does the axis of the syncline dip, northeast to southwest or *vice versa?* Why is Third Mountain pointed? Why does it widen to the eastward? Taking the diagram, Figure 25, has the syncline of which Peters Mountain and Second Mountain are a part reached the line *aa* or *bb*? Which lines has the level part of Third Mountain reached?

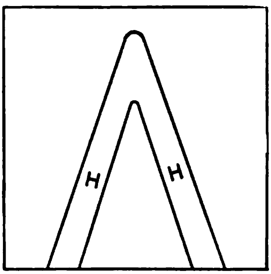


FIG. 26.

The valley of Cove Creek, locally called "The Cove" (New Bloomfield Quadrangle), has been called a "canoe valley." What appropriateness has this name? Explain the origin of Cove Creek Valley.

96. LAND FORMS RESULTING FROM THE EROSION OF A PITCHING ANTICLINE

Staunton Quadrangle, Virginia–West Virginia. — What are the heights of Walkers Mountain and Side-

ling Hill at their highest points? At their lowest points? What kind of structure have they (see Figure 27)? What kind of rock makes them? When an

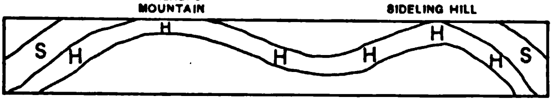


FIG. 27.

anticline is eroded, do its outcrops recede from each other or approach each other (see Figure 28)? How does this compare with a syncline? The axis in Fig-

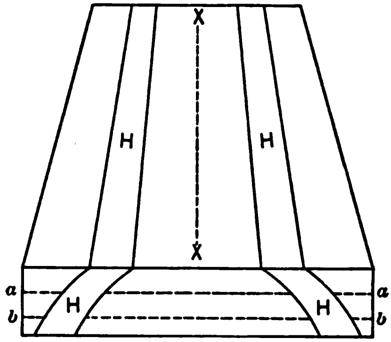


FIG. 28.

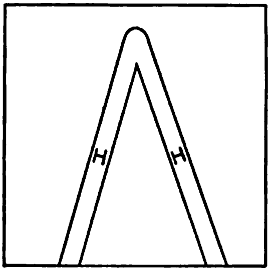


FIG. 29.

ure 28 is pitching or dipping toward the top of the page. As the anticline is eroded, will it become narrower or broader equally at both ends? As erosion proceeds, the outcrops, *HH* in Figure 28, will finally have the position shown in Figure 29. Why? Has

the anticline which makes Walkers Mountain and Sideling Hill a pitching axis? Why? Which way does it pitch? Illustrate by a block diagram.

Why are there no monoclinal ridges as in the Grantsville, Md., Quadrangle? What stream in the vicinity is a good example of a subsequent stream?

New Bloomfield and Harrisburg Quadrangles, Pennsylvania.—Trace Half Falls Mountain. What is its shape? Do you think it extends into or across the Susquehanna River? What is the horizontal outline of the mountain? What is the structure of Half Falls Mountain and the adjoining ridges (see Figure 30)? Has the folding a horizontal or a pitching axis? How do you know? Which way does the axis pitch? How do you know? Classify and give your reasons as to whether Half Falls Mountain, Mahanoy Ridge, and Hickory Ridge are anticlinal mountains or monoclinal ridges.

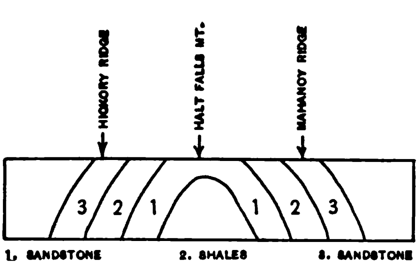


FIG. 30.

97. STREAM ADJUSTMENT IN FOLDED STRUCTURE

New Bloomfield Quadrangle, Pennsylvania.—Trace the western Fishing Creek which flows into the Susque-

hanna at Marysville. Note the tributaries. What is notable in the headwater regions of the longer tributaries? Do all the longer ones show this peculiar pattern? Note Trout Run. Through what kind of rock is its lower course cut (see Figure 31)? Its upper course? Why, then, does Trout Run bifurcate in its upper course? Why do not the shorter tributaries bifurcate? As Trout Run extends its headwaters along

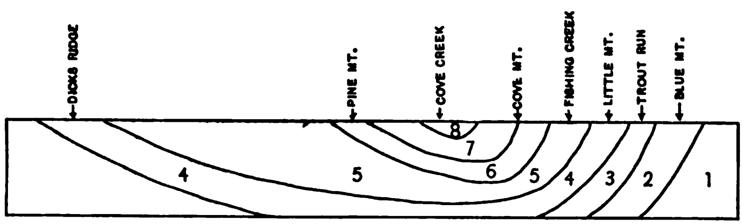


Fig. 31.

the belt of weaker rock, it will ultimately capture or be captured by other similar tributaries. In this way the valleys will be opened out. When the streams of a country are flowing on the weaker rocks they are said to be *adjusted*. Is the adjustment in this region complete? Is it well advanced? When would fairly complete adjustment come, in youth or in maturity? Sketch an example of complete stream adjustment; of an incomplete adjustment.

*98. STREAM CAPTURE IN FOLDED ROCKS

Harper's Ferry Quadrangle, Virginia–West Virginia–Maryland. — This region formerly was peneplained, the peneplain sloping southeasterly. Upon this peneplain the Potomac, Beaverdam Creek, and other streams were established. When these streams began to cut through the Blue Ridge, which stream, the Potomac or Beaverdam Creek, would cut the faster? Why? Which tributaries, those of the Potomac or Beaverdam Creek, would extend faster along the weak rocks of the present Shenandoah Valley (Figure 32)? The Shenandoah began as a short tributary to the Potomac. It extended rapidly southwest along the belt of Weak Rocks. (Give two good reasons.) The Shenandoah captured the headwaters of Beaverdam Creek. Why should it do so? From the above facts, explain Snickers Gap and the two streams heading from the gap. How deep is the gap? How high above the Shenandoah Valley is the floor of the gap? How

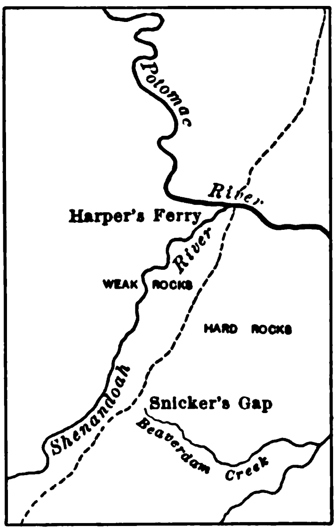


FIG. 32.

long is the gap? Is it a "wind gap" or a "water gap"? Find examples of a wind gap and a water gap in this map, and sketch them. Draw sketches to illustrate the process of stream piracy in connection with Beaverdam Creek. What factors affect stream capture here that are not operative in the Kaaterskill, N.Y., region (Exercise 64)?

What changes in the width of the Potomac Valley and in valley slopes above and below Harper's Ferry? Why?

What strategic importance had Harper's Ferry in the Civil War? What is the geographic basis for this importance?

99. THE EFFECT OF A CHANGE IN DIP UPON THE WIDTH OF OUTCROP

PART I. *Huntington Quadrangle, Pennsylvania.*— What is the height of Allegrippis Ridge? What is the structure (see Figure 33)? The ridge is composed of sandstone and conglomerates in this region. The dip of the rocks making

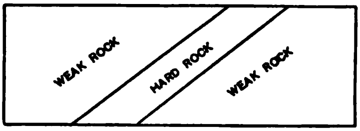


FIG. 33.

Allegrippis Ridge, in Hopewell Township, is about 38°, and in Juniata Township, about 20°. What is the width of the ridge in Hopewell Township across the letter *L* in Allegrippis? In Juniata Township about two miles north of Hawn Bridge?

Which makes the wider outcrop, the lower dip or the higher dip of a bed? Why? Draw to illustrate.

PART II. *Briceville Quadrangle, Tennessee.*—The rocks forming Black Oak Ridge dip southeasterly, but the amount of dip varies. Judging from the varying width of the ridge, where is the dip steepest? Where least steep? Draw diagrams to illustrate.

With a given structure, what dip would give a minimum outcrop? A maximum outcrop?

REFERENCE.—The Huntington Quadrangle is described in the volume on Huntington County, Second Geological Survey of Pennsylvania. The Briceville region is described in the Briceville Folio, U.S.G.S.

100. PENEPLAINS

Harrisburg Quadrangle, Pennsylvania.—It is believed that two ancient peneplains are to be found in this region. If you were to fill up the valleys in the lowland south of Blue Mountain, what kind of a surface would you have, smooth or rough? How high above sea level? How does this height agree with the elevation of the valleys between the larger ridges?

What would be the elevation of such a plain in the valley north of Peters Mountain? (This is considered as belonging to the peneplain in the vicinity of Harrisburg.) Which way does the peneplain slope? How much below it is the valley of Paxton Creek cut? Of Powell Creek? Is the incised meandering valley of

Conodoguinet Creek of any significance in connection with this peneplain?

If you imagine the valleys between the ridges to be filled, what kind of country would you have? How high above sea level? How high above the peneplain in the Harrisburg region? This peneplain, the remnants of which are the ridges, has been called the Kittatinny Peneplain. How far below this peneplain has the Susquehanna cut its valley? How would the course of this river across the mountains be explained? Why have the ridges been preserved? *The lower peneplain is discussed by M. B. Campbell, Bull. G.S.A. Vol.* 14, *pp.* 277–296.

Supplementary Questions. Harrisburg Quadrangle, Pennsylvania. — How high above the river is the terrace upon which most of Harrisburg is built? How wide? Can you trace the terrace on the west side of the river? Why? Trace the course of Paxton Creek. At about what angle does it enter the Susquehanna Valley? The Susquehanna River? Did the river ever cover the present terrace? At that time do you think Paxton Creek followed its present course parallel to the river? Why? What is the probable reason why it does so now? Find examples of wind gaps. Of water gaps. What contrast in the arrangement of roads in the ridge region and in the plain region?

*101. STAGE OF EROSION IN TOPOGRAPHY DEVELOPED ON FOLDED ROCKS

(In the Raritan Quadrangle, use only the region northwest of the Fox Hill Range.)

Ellensburg, Wash., Harrisburg, Pa., and Raritan, N.J., Quadrangles. — Compare the three regions as to dissection, adjustment of streams, sharpness of crests. Sketch type examples. (In the Raritan region, the drainage north of 40° 50′ is disorganized by glaciation.) Classify them, and give full reasons, into youthful, mature, and late mature regions.

102. MONOCLINAL SHIFTING

What is a monocline? It may be illustrated by Figure 34. The rocks are inclined. Which way do they dip in the figure? As the surface *AB* is eroded, will the outcrops *H* and *S* remain in the same relative position, or will they migrate? What will the positions of the outcrops be when the surface is eroded to *XX*. Draw. Does the outcrop of monoclinal strata migrate *with* or *against* the dip of the strata? Such shifting is termed monoclinal shifting.

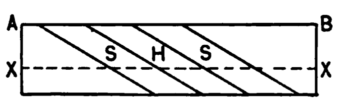


FIG. 34.

Holyoke Quadrangle, Massachusetts. — The Holyoke Range is of trap rock, with a structure shown in Figure 34. The trap rock *H* is overlaid and underlaid by

softer sedimentary rocks. All the rocks in the vicinity dip eastward. At several points, the range is crossed by faults (dip faults). The region on one side of the fault has been elevated, as in Figure 35. As this upthrown block is eroded, which way will the outcrop *H* migrate? After the upthrown block is eroded even

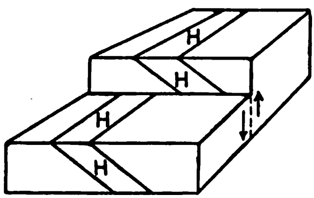


FIG. 35.

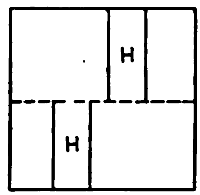


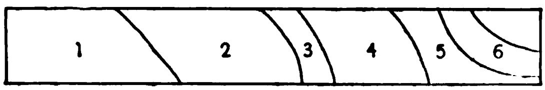
FIG. 36.

with the other block, will the outcrop of *H* in each block meet? If not, on which block will *H* be most easterly? The result, after erosion, would be as in Figure 36. If you had the converse problem of determining which is the upthrown side, by knowing which side showed a migration with the dip of the rock, how would you determine it? For example, south of Sheldon Hill the Holyoke Range has shifted somewhat eastwardly. Which is the upthrown side? Draw to illustrate.

*103. "HOG BACKS"

Denver Quadrangle, Colorado. — Two great features are shown here, the Great Plains and the eastern front of the Rocky Mountains. How high above sea level

are the plains? How high is the Rocky Mountain Range, shown on the western edge of the map? Locate Denver, South Platte River, Golden. South of Golden are ridges known as "hog backs." How high, in general? What is the average width? They are caused by outcrops of Dakota sandstone (see structure section,



1. CRYSTALLINE ROCKS 2. SHALES AND SANDSTONES
3. SANDSTONE (DAKOTA) 4. SANDSTONES AND SHALES,
5, 6. SHALES, SANDSTONES AND CLAYS

FIG. 37.

Figure 37). What is the structure — anticlinal, synclinal, or monoclinal?

Make a profile across the ridge west of Littleton (south of Denver). Which slope is steeper? Why? Which, less steep? Why? What seems to account for the breaks in the ridge? The parallel ridges near Deer Creek are due to a hard layer in the stratum underlying the Dakota sandstone (Wyoming formation). Why is there a valley between the hog backs and the mountains? The Table Mountains, west of Denver, are capped by basalt. How do their slopes differ from those of the ridges?

Irrigation. — Note the irrigation canals. How do their courses differ from the average stream course? Do you find any canals that are parallel to the con-

tours? What is the greatest distance from the stream that any canal extends? What advantage for irrigation does this region have?

REFERENCE. — The region is described in Monograph 27, U.S.G.S. (Geology of the Denver Basin).

104. A CUESTA

Trenton, N.J.-Pa., and Navesink, N.J.-N.Y., Quadrangles. — In what part of New Jersey is this area? Draw a profile, using only 100-foot contours, from Silver-

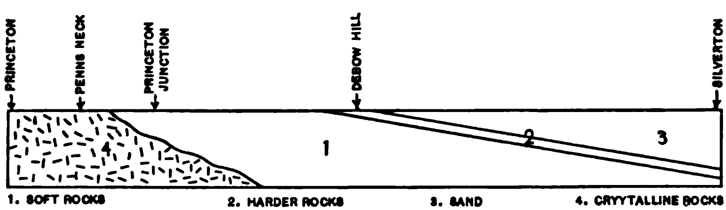


FIG. 38.

ton (southeastern part of Navesink Quadrangle) through Debow Hill to Princeton. Use the scale of one inch to the mile, and paste the parts of your profile together so as to make it continuous. Below your profile, draw to show the kinds of rock underlying the country (see Figure 38). What is the arrangement of the rocks east of Princeton? Which way do they dip? What rocks make highlands? What, lowlands?

Explain the origin of Debow Hill. Is this hill isolated, or is it a portion of a serrate ridge? Are the

slopes of this ridge equal? Which direction is the steep slope? The gentle slope? How are these slopes associated with the structure (*e.g.* Debow Hill)? Would you be likely to have such slopes if the rocks were homogeneous? Would you, if the dip of the rocks were vertical? Why? A cuesta is a ridge resulting from such a structure. It has a gentle outer slope and a steep slope facing the inner lowland. Trace the cuesta and inner lowland. How many rivers occupy the inner lowland? Name them. What large river occupies it in part?

CHAPTER XI

LAND FORMS DUE PRIMARILY TO FAULTING AND VOLCANISM

105. A FAULT SCARP BUT LITTLE DISSECTED

*PART I. *Mount Trumbull, Ariz., Quadrangle.*—In what part of Arizona is this quadrangle? Hurricane Ledge is caused by a fault. Which side is upthrown? Which, downthrown? What is the average height of Hurricane Ledge? Where does it end?

What can you infer as to the rainfall of this region? What are your reasons? What effect has this rainfall on the dissection of the fault scarp?

In what general physiographic division of the United States is this region?

PART II. *A Dissected Fault Scarp. Austin, Tex., Quadrangle.*—What two divisions of the regions so far as altitude is concerned? How much of the quadrangle lies at, or below, 750 feet altitude? How much above 1000 feet altitude? Between these two altitudes are a series of parallel faults. Trace the belt between these two altitudes across the map. How much is the slope per mile, on the average, in the fault zone? Has the faulting been recent? Why?

The escarpment is known locally as the Balcones, and the region west is known as the Mountains. Why is the term mountains applied to the region west of the Balcones? What difference in dissection is there between the mountains and the plain? How do the hills differ in the two areas in slopes and height? How does the width of the Colorado Valley differ in the two divisions?

What would account for the contrast in distinctness of the fault scarps in this region and in the Hurricane Ledge?

*106. BLOCK MOUNTAIN AND RIFT VALLEY

Alturas, Cal., and Long Valley, Nev., Quadrangles.— In what part of their respective states are these areas? How long is Warner Mountains? How high above sea level? How broad is the mountain? Does it most resemble the Catskill, Rocky Mountains, Col., Mount Mitchell, or the Appalachian Ridge (Harrisburg, Pa., region) type? Make a profile along parallel 41° 30′. Are the slopes equal? Where do the slopes begin to become steeper as you go from the crest toward the west? What is the slope per mile from the crest to Alturas Hill? To Surprise Valley? Change these slopes into degree reading (either by construction and measurement of the angles, or by trigonometry). Is the crest sharp? What is the structure underlying

these mountains (Figure 39)? The rock is of rather homogeneous crystallines. How does the structure explain the slopes? The crest?

A fault runs parallel to the base of the mountains, and some of the faulting is so recent that alluvial cones have been faulted. Which is the upthrown side of the fault? The downthrown side? Which streams, the eastward flowing or the westward flowing, have the longest course? Why? The steepest slopes? Why? Compare the dissection of the fault scarp with that in the Austin, Tex., region.

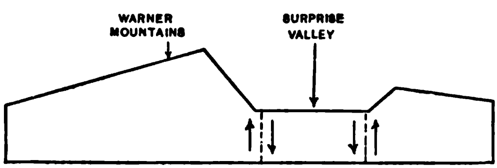


FIG. 39.

Surprise Valley.—From the diagram, determine the origin of Surprise Valley. Is there an outlet for its drainage? Why, then, do not the lakes fill up the valley? Why should the middle lake be called Alkali Lake? How far is the valley below the uplands? Which fault scarp, east or west, has the greatest height? Which is most dissected? Which is most distinct?

Long Valley has an origin similar to that of Surprise Valley. How far is the valley below the uplands? Make a diagram illustrating its origin. How would you distinguish it from a normal erosion valley? How would you explain the drainage? What kind of lakes

are those east of Alkali Lake? What does the name of Alkali Lake suggest as to the climate? Note the elevation about four miles east of Alkali Lake. What origin do its slopes suggest? Illustrate by a profile and diagram.

107. REVIEW. EROSION FORMS ON FOLDED AND FAULTED STRUCTURE (STRIKE FAULT)

Gadsden Quadrangle, Alabama.—Note Red Mountain and Straight Mountain. Do they seem to unite? Do you think they belong to one structure or to different structures? Why? Do they unite in a point? Where else have you seen ridges meeting in a point? What does this indicate, if the structure is synclinal? If anticlinal? Can you infer, by the slopes, what the structure is? Why do the streams make any such inference unsafe? Does Red Mountain have any peculiar topography? How does it differ in topography from Straight Mountain? What is the structure (Figure 40)?

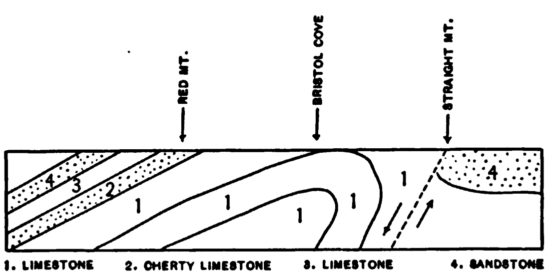


FIG. 40.

Which way does the axis probably dip? What rock makes the unnamed ridge west of Red Mountain? What influence on the slopes of this ridge has the dip of the sandstone? What rock makes Red Mountain? How far does the knobby topography of Red Mountain extend? A fault parallel to Straight Mountain begins east of Aurora and runs southwest. This has its downthrown side on the west, and the bed that made Red Mountain has been carried down, while the same bed that makes the ridge west of Red Mountain makes Straight Mountain. How is the fault indicated by the topography?

*108. A VOLCANIC MOUNTAIN

Shasta Special Quadrangle, California. — Mount Shasta is a young volcanic mountain which has not as yet been greatly eroded. Various coulees are found about the mountain, where lava has escaped. Among them are Lava Park, and lava flows at various localities. The lava from the coulees rapidly cooled and hardened quickly before the flow could spread out. In general, therefore, the margins of these flows are bounded by rather steep cliffs. Why? Note the lava flow in the northeastern corner. This had its origin at about 10,000 feet. Where is its margin? How long is the coulee? Trace, likewise, the limits of the lava flow at Lava Park. Note an unnamed lava flow about five

miles southwest of Shastina. Beginning with Bear Butte. there is a line of hills running up the mountains, including Cinder Cone, Gray Butte, and Red Butte, These are all lava cones except the two cinder cones.

Trace the routes to the summit from the railroad near Sisson. Why does the right-hand route zigzag up the mountain beyond Mud Creek? Why does the railroad zigzag in the southwestern part of the map?

REFERENCE. — The chapter on Mount Shasta by J. S. Diller in "The Physiography of the United States."

*109. A DISSECTED VOLCANIC MOUNTAIN

Marysville Quadrangle, California.— Marysville Buttes is a partly dissected volcano, with a central core of igneous rock and a surrounding zone, largely composed of tuffs and breccias derived from the central core. Copy the general outline of the Buttes. (This can well be done through transparent tracing paper.) The inner core of hard volcanic rocks may be outlined roughly as follows: from the letter *A* in Marysville to a point about two miles north of the letter *S* and thence to the letter *L* in the same word; from *L* to the letter *E* in the word Buttes; from this point to the letter *B* in the same word, and thence to the point of beginning. This will give the general area of hard rock. (If the Marysville Folio is at hand, use the geological map.) Outside of this area is the zone of derived and softer rock.

Compare the two zones as to erosion. What average height have Marysville Buttes? What average diameter? What is the slope per mile of the sedimentary zone? Of the igneous zone? Explain the difference.

REFERENCE. — Marysville Folio, U.S.G.S.

110. LACCOLITHIC MOUNTAINS

Henry Mountain Quadrangle, Utah. — In what part of the state is this area? How far, and in what direction, from Salt Lake City? The Henry Mountains are good examples of laccolithic mountains. Compare the peaks with mountains of circumerosion; with folded mountains. How high are the four principal peaks above sea level? Above the general level of the plateau? Are the slopes steep? Are they more steep in one direction than in another? Considering the origin of these peaks, is there any reason why they should have a round, rather than a linear, shape? Mount Hillers has a main laccolith with two smaller ones to the northeast. Find the two hills made by these. How high are they?

REFERENCE. — Report on the Geology of the Henry Mountains, C. K. Gilbert, U.S.G.S.

*111. A VOLCANIC NECK

Austin Quadrangle, Texas.—Pilot Knob is an example of a volcanic neck. What is its height? Diameter?

About what is its area? Why should Pilot Knob stand above the surrounding country? An outcrop of volcanic materials is found near Bluff Springs to the west. At least how far from the volcano has the eruptive material been spread in this case? Might it have been carried farther and leave no record?

REFERENCE. — Austin Folio, U.S.G.S.

112. TOPOGRAPHY DUE TO A DIKE

New Bloomfield Quadrangle, Pennsylvania. — Ironstone Ridge (southern part) is caused by a dike. Is its rock harder or softer than the surrounding rock? How high above the adjacent country? Trace the ridge as far as you can. What is the probable significance of the name of the ridge? What political boundary does the ridge form?

*113. LAVA CONES AND CINDER CONES

The steepness of slope of a cinder cone is from 30° to 40°. That of a lava cone made by very fluid lava may be as low as 6° (Mauna Loa, Hawaiian Islands). Why should there be so great a difference? Using the same scale, construct an angle of 6° and 30°. Show the same by an ideal contour drawing of the two cones, using the same scale and contour interval.

*114. A SILL

Harlem Quadrangle, New York–New Jersey. — The steep cliff facing the Hudson on its western side is the Palisades (read description). It is a sill which has been elevated and tilted toward the west (see structure section,

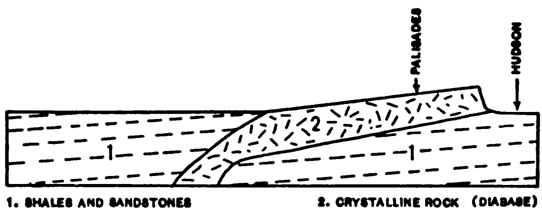


FIG. 41.

Figure 41). How high is the crest above the river? Make a profile across the Palisades. What is the slope per mile of the Palisades to the Hudson? To the westward? What reasons are there for the steep eastward slope? For the more gentle westward slope? To which of the formations is the Palisades due?

REFERENCE. — New York City Folio, U.S.G.S.

CHAPTER XII

GLACIATION

*115. ALPINE OR MOUNTAIN GLACIERS

Shasta Special Map, California. — Where is Mount Shasta? How far, and in what direction, from San Francisco? How many glaciers can you find? Are they all united? Where are some united, at their heads or at their margins? How would you explain this? Why is not the top of the mountain covered by ice? Does the ice occur for the most part in valleys or on ridges? Why? How deep is the valley leading away from Wintun glacier (near the foot of the glacier)?

Are the glaciers equally long? Equally broad? Equally large? About how many square miles in Hotlum glacier? Is there more ice in any one direction than in another? How would this be explained by (1) direction of slopes, (2) catchment area? What is the lowest limit of the ice on the north side? On the south side? How high is Mount Shasta?

116. CIRQUES (ALPINE GLACIATION)

Gilbert Peak Quadrangle, Utah–Wyoming.—In what part of Utah is this quadrangle located? How far,

and in what direction, from Salt Lake City? How high are the Uinta Mountains? How high above the average level of the surrounding country? Would you describe the drainage as youthful or mature? Do the lakes all have outlets? This region shows good illustrations of cirques (amphitheater-like openings at the head of valleys). The one containing Lake Atwood (central part) is a good example. How many cirques can you find? What is the average height at which they are found? What drainage features are usually found in their basins? About how many square miles in the cirque containing Lake Atwood? Make a profile through this cirque to the Uinta River. In what part of its course is the valley steepest? Least steep? Where is the valley widest? What is its slope per mile in the fairly level portion? In the steep portions? Compare the profile with that of the streams in Exercises 65, 66, 67. How do their upper, middle, and lower courses compare in slope, steepness of valley sides, and width of valleys? The small isolated lakes without outlets occur in the moraines built by the glaciers. How high upon the mountains do they occur? Do you think that cirques are the result of constructive or of destructive work of the ice? Why?

*117. U-SHAPED AND HANGING LATERAL VALLEYS

Telluride Quadrangle, Colorado. — A valley glacier extended down the valley of the Lake Fork of the San Miguel River. Make a profile across this valley at Belt Ranch and one across the valley of Bilk Creek, east of Diamond Hill, using the same scale in each profile. How do these profiles compare in shape? Which is *V*-shaped? Which is *U*-shaped? Which valley do you think has been shaped by ice erosion? Which, by water erosion?

Make a profile of Vance Creek. Where are its steepest slopes? Do normal streams have their steepest slopes at their heads or at their mouths? Vance Creek Valley is an example of a *hanging* valley. How high does it "hang" above its main valley? How do normal streams enter their main streams, at grade or hanging? Explain the behavior of Vance Creek. Find and sketch other examples of a main *U*-shaped valley and its hanging lateral valley.

Compare the valley sides of the San Miguel River with those of the Chattahoochee River (Marietta Quadrangle, Georgia) and of the Buffalo Fork of the White River (Marshall Quadrangle, Arkansas). How do they compare in general smoothness of outline? In the sharpness of their spurs? Sketch good examples. Explain the contrasts.

Compare the number of towns with those of the Marshall, Ark., and Marietta, Ga., regions. How would you account for the population of the sterile Telluride region?

REFERENCE. — Telluride Folio, U.S.G.S.

*118. MARGINAL MORAINES

Islip Quadrangle, New York. — In what part of Long Island is this quadrangle situated? How wide is the island here? How many belts of highland? What is the general height of each belt? How many belts of lowland? What is the general height of each? Does the southern lowland hold its elevation, or is it sloping? Make a profile across the island through Babylon. What is the slope (per mile) of the southern lowland? Which have the most even surface, the highlands or the lowlands? Compare the hydrography of the two.

There are two moraines and two outwash plains running across Long Island. The moraines have considerable till, while the outwash plains are composed largely of sand and gravel. Can you identify the moraines by their greater altitude? Which feature has the greater number of undrained ponds? Does this fact have any relation to the composition of the moraine? Are there any depressions without water in them? Where are they situated? How far above sea level is the surface

of Lake Ronkonkoma? How much below the general altitude of the moraine is this surface? How many streams on the southern outwash plain? What relation does the number of streams have to the materials composing the plain? Do the streams have many tributaries? What relation does this fact have to the sandy character of the plain? Where are the slopes of the outwash plain steepest, near the moraine or distant from it? What relation has this fact to the origin of the outwash plain?

Whitewater Sheet, Wisconsin. — A terminal moraine extends across the map northeast from Whitewater Lake. Is it, as a whole, higher or lower than the adjacent country? How much? What is its average width? How would you describe the surface of the moraine? Are there depressions? By what kind of a contour line are these depressions indicated? About how deep are most of them? How deep below the general level is the pond about three miles southeast of Palmyra? Would the description "hillock and hummock" apply to the surface of the moraine? Are the ponds and depressions such as would be produced by the usual processes of erosion? The ice by which the moraine was built lay on the northwestern side. Make a profile across the moraine from Palmyra to Country Lake. Which slope is steepest, the northwest or southeast? Why should it be steep on the ice side?

What features do you find similar to the moraine on Long Island?

*119. COMPARISON OF GROUND MORAINE AND MARGINAL MORAINE

Whitewater, Wis., or St. Paul, Minn., Quadrangle and Mount Sterling, Ohio, Quadrangle. — Where is a marginal moraine built? A ground moraine? The Mount Sterling region is covered with a ground moraine largely composed of till. How does the surface of a ground moraine compare with that of a marginal moraine, as to smoothness and drainage? Find, and sketch, types to illustrate your answer. Which kind of moraine makes the best agricultural land? Why?

120. A COMPARISON OF MOUNTAINS MODIFIED BY MOUNTAIN OR ALPINE GLACIATION AND BY CONTINENTAL GLACIATION.

Mount Marcy Quadrangle, New York, and Gilbert Peak Quadrangle, Utah–Wyoming. — The Adirondacks were overridden by the continental glacier, while the glaciation in Utah was of the Alpine type. What is the height of Mount Marcy? Of Gilbert Peak? What glacial features are common to both regions? What are peculiar to Alpine glaciation? Which type of glacial erosion produces the smoothest topography? Which topography could you characterize as *smoothed?* As *sharpened?* Sketch good types of both examples of glacial erosion.

*121. A COMPARISON OF MOUNTAINS AFFECTED BY GLACIAL EROSION AND BY SUBAËRIAL EROSION

Mount Marcy, N.Y., Gilbert Peak, Utah–Wyo., Mount Mitchell, N.C.–Tenn., Quadrangles. — Compare Mount Marcy, Gilbert Peak, Mount Mitchell, and Blue Ridge as to dissection. Which have sharp outlines? Which are most dissected? Which mountains have the steepest slopes, those due to glacial erosion or those due to subaërial erosion? Which type does Mount Mitchell the more resemble, Gilbert Peak or Mount Marcy? How could you distinguish them? How could you distinguish them by their drainage features? How does a cirque differ from the head-water region of a stream due to subaërial erosion? Is Mount Mitchell an isolated peak or a part of a range? How do the Black Mountains differ from the Uinta Mountains? How would Mount Marcy differ from its present appearance if it were due entirely to subaërial erosion instead of partly to glacial erosion? How high is Mount Mitchell? Mount Marcy? Gilbert Peak?

Sketch a good example, not before mentioned, of a mountain characterized by subaërial erosion, by Alpine glaciation, and by continental glaciation.

*122. GLACIAL EROSION. FIORDS

Boothbay Quadrangle, Maine. — In what part of the state is this region? What is the general shape of the

islands and peninsulas? Are the divides straight or markedly curving? Are the bodies of water long or round? How do they compare in this respect with the Wisconsin maps? How do Sheepscot and Damariscotta rivers compare with Poquoson and Back rivers of the Hampton, Va., Quadrangle? In what respects are they similar? In what, different? How do the valley sections and divides compare? Which have the best developed tributaries? Which, do you think, are the product of normal erosion? Why? From a map of Maine, determine the length of the Sheepscot and Damariscotta rivers. Are they longer or shorter than Poquoson and Back rivers? In which region, the Boothbay or the Hampton, does the land slope *gradually* toward the sea?

During the glacial period the ice moved over the Boothbay region in a general north-south direction. What effect would this movement have on the existing river valleys? What effect would it have on the development of tributaries, as compared with the Hampton region? Such long, narrow arms of the sea are called *fiords*. How deep is the Sheepscot River below the general elevation of the region? West of Barter Island the water is 12½ fathoms deep, and west of Southport Island the water is about 24 fathoms deep. How deep is the bottom of the fiord below the general level? If coast charts Nos. 314 and 315*a* are at hand, note the depths of other fiords.

Find all contrasts you can between the erosion forms of the Hampton, Va., region and the Boothbay region. Illustrate by sketches the best types you can find.

*123. A DIVERTED STREAM (GLACIAL)

Rochester Special Quadrangle, New York. — How wide is the valley of the Genesee River at the southern border of the map? Below Rochester? What is the altitude above sea level of the river just north of Genesee Junction? At its mouth? How high are the falls in the city of Rochester? (*Suggestion:* Trace the 500-foot contour into the city, and note when it crosses the river, and then note the height below the falls.) Are there any other falls below the city? How high are they?

Trace on some general map the course of the Genesee River. Where does it rise? Are falls to be expected in the upper or lower courses of the river, if they occur at all? Is the stream valley usually wider at the mouth or upstream from the mouth? Explain your answer to the preceding two questions, as they may be affected by volume and fall of stream. How do your answers apply to the Genesee in this region?

Compare the tributaries of the river above and below Rochester as to number, length, and width. To what stage, youthful, mature, or old, does the valley north of Rochester belong? South of Rochester? The Genesee River has been blocked by glacial action and compelled

to cut a new channel. About where in this vicinity did the blocking occur?

REFERENCE. — Tarr's "Physical Geography of New York State," pp. 164–167.

*124. DRUMLINS

Sun Prairie Sheet, Wisconsin. — In what part of Wisconsin? What is the distance and direction from Milwaukee? About how high is the plain on which the drumlins stand? Are the drumlins of uniform height? How high is the highest above the adjacent country? The lowest? What variation in height? How would you describe the ground outline of the drumlins? Make a north-south profile and an east-west profile across the drumlin east of Sun Prairie. In general, are the north slopes and the south slopes equal? Note the double or "twin drumlins" southwest of Cottage Grove. Where are others? With the protractor get the direction of the longer axis of the following drumlins (*e.g.* the direction of axis of the drumlin east of Sun Prairie is north, east 43°): east of Goose Lake, east of Mud Lake, south of London, west of Cambridge, south of Nora, southwest of Hope, north of Vilas, north of Adsit, southwest of Sun Prairie, northwest of Sun Prairie. What evidences of glaciation, other than drumlins, do you find in this region?

125. COMPARISON OF GLACIAL EROSION AND GLACIAL DEPOSITION

Boothbay, Me., Whitewater, Wis., and Mount Sterling, Ohio, Quadrangles. — Which of these regions represent glacial deposition? Which glacial erosion? Which region has a *smoothed* topography? Which a *smooth* topography? Is stream development better in the Mount Sterling or the Boothbay region? How would you explain your answer? Which region has the roughest topography? Which region has the highest hills? Which, the deepest valleys? Which has the best drainage? Which, the poorest? Which region do you think has the best agricultural land? Which, the poorest? Why? Sketch a good example three miles square of ice-eroded topography; of marginal moraine; of a ground moraine.

126. SAND PLAINS AND ICE-CONTACT SLOPES

Abington Quadrangle, Massachusetts. — How far, and in what direction, is this region from Boston? Extending from Northville is a line of hills curving to the southwest, and at East Bridgewater the line curves to the northwest. About a mile and a half south is another line of hills parallel to this. Do these hills, as a rule, have slopes equal in all directions? In general, are their short slopes in the same direction? Their long slopes? Have any of the hills lobes?

A lobe of ice extended down the valley of the Matfield River. (Why should it extend farther south in the valley than on the uplands?) Streams from this ice built cones and deltas at the ice margin. Would such a form be steepest on the ice-contact side or on the out-wash side? Why? Would some of them be lobate? Why? Sketch a good example of a hill showing the ice-contact slope and the out-wash slope. Sketch a good example showing a lobate outline. Draw a map showing the successive positions of the ice front as shown by the lines of hills.

127. GENERAL EXERCISE

Watkins Quadrangle, New York. — This region was overridden by the ice of the Wisconsin period. The valley in which Seneca Lake is located was scoured. How much the valley is due to ice action is yet uncertain. Later, while the ice was retreating, this valley contained a lake which drained southward through the present valley of Catharine Creek. See the Watkins Glen Quadrangle, and trace the valley of Catharine Creek. Does this creek occupy the entire valley? Where are its head waters? How would you describe the divide between Catharine Creek and Newtown Creek? Is this a normal divide? Why? Compare it with other divides, *e.g.* between Bulkley Creek and Cayuta Creek.

What evidence north of North Elmira that the outlet of the old Seneca Lake discharged through the valley? What bearing has this on the exercise?

Hanging Deltas.— Along the larger creeks as at Watkins Glen and Hector Falls, you will note that the contours bow out. What do these forms indicate — a ridge, a valley, or level ground? Is such a feature normal in the lower part of the valley? Do the tributaries of these creeks have them? These forms are deltas built by the creek when the lake was at higher levels; and when the lake surface was lowered, the streams cut through their deltas. How many levels can you find? What do these levels show — a stationary, rising, or a lowering surface? Do these levels correspond in elevation on the deltas of different streams?

Ice Erosion. — How would you describe the slopes of the valley sides of Seneca Lake? Their dissection? Are the ravines deep? Compare in this respect with the valleys of the Chemung, Elmira, N.Y., Quadrangle, and Ohio, Charleston, W. Va., Quadrangle. What relation has this smoothness of valley side to ice action?

Note Big Hollow Run, north of Watkins. Make a profile of the stream. Is this profile a normal one? Give full reasons for your answer. Do most of the streams running east or west into the lake have a similar profile? Does Catharine Creek have a similar profile? Where have you seen profiles similar to that

of Big Hollow Run? What is their significance? Why does Catharine Creek not have a similar profile?

Deltas. — What kind of topography at the head of Seneca Lake Valley? How was it made? Is its margin stationary, advancing, or retreating? Explain the points of low land along the lake shore opposite each creek.

REFERENCE. — Tarr's "Physical Geography of New York State," p. 176.

128. GENERAL REVIEW

The following quadrangles mounted together: Minneapolis, St. Paul, White Bear, and Anoka (Minn.) Quadrangles. (For a class of average size, one or two mounted maps will be sufficient.)

The St. Paul Quadrangle shows a fine example of a moraine. What features of topography and drainage are characteristic of a moraine? Are these features as prominent in St. Paul as in the surrounding country? Trace the moraine on the mounted map. Where is it most marked? How high is the moraine on the average? How high is the region in the northern part of the grouped maps? What kind of a moraine is it here? What kind in the southern part?

Make a cross section of the Mississippi Valley at South St. Paul and in Minneapolis. How do they compare in all respects? How do they compare with the valley above Minneapolis? How with the valley

of the Minnesota River? Compare the Mississippi above Minneapolis; between Minneapolis and Pike Island; below Pike Island and the Minnesota Valley, with respect to how they *fit* their valleys. Where are St. Anthony Falls? How high? Do falls or rapids remain stationary or do they migrate? Why? Which way do they migrate, up- or downstream?

How high are Minnehaha Falls? How far have they migrated since their origin? The Mississippi River once followed the valley of the Minnesota. The preglacial Mississippi was blocked by a moraine and compelled to make a new channel, and the river joined its old valley at Pike Island. Explain the foregoing features in the light of this history. What was the origin of St. Anthony Falls? Where did they begin? Why have they receded farther than Minnehaha Falls? What physiographic feature determined the location of each of the "Twin Cities"? For what manufacture are they notable? What strategic value has Fort Snelling?

*129. A COMPARISON OF DRIFTLESS, NEW DRIFT, AND OLDER DRIFT AREAS

Lancaster, Wis., Portage, Wis., and Anamosa, Ia., Quadrangles. — How many square miles in the Lancaster area? How far, and in what direction, is Lancaster from Chicago? What is the average height

of the region above sea level? What average depth have the deeper valleys? What is the shape of the cross section of the principal valleys? Of the minor valleys? Have all of them flood plains? Have any of them flood plains? How wide is the widest flood plain? Do flood plains occur in the upper or lower part of the valleys? Make a profile of Platte River, from Annaton to its mouth. What is the rate of descent in its upper part? Its lower part? What is the height of the plateau east of Annaton? What is the slope of the country from there to the mouth of the Platte River? How would you describe the divides, as broad or narrow? Is the run-off good or poor?

The quadrangle is a portion of a dissected plateau. What remnants of the plateau? Where? What is their general height? What proportion of the original plateau surface, would you estimate, remains?

Portage, Wis., Quadrangle. — How far, and in what direction, from Lancaster is Portage? In what part of Wisconsin is Portage? How far, and in what direction, from Milwaukee? How do the valleys compare in cross section with those of the Lancaster map? How deep are the valleys? How does this depth compare with that of the valleys in the Lancaster region? Which way does the Fox River flow? Can you determine by the contours? What is the length of the Fox River? About what is the fall per mile in this region? How

does this compare with that of the rivers in the Lancaster region? What do you notice about the width of Fox River Valley? Is it uniformly wide? Does it widen downstream? Do most stream valleys widen downstream? How would you describe the divides? How do they compare with those of the Lancaster region? How do you describe the run-off? Which would be more subject to floods, the rainfall being equal, the Fox or the Platte River? How much of the area, do you estimate, is in swamp? How much is covered by lakes? How does the number of tributaries in this region compare with that of the Lancaster region? Where are most of the roads in the Portage region? Where does the Fox River lead? The Wisconsin? How are they connected? How high is the divide between them? This was an old canoe portage before the canal was dug, hence the name of the city. This region is overlaid with drift of late Wisconsin age.

Anamosa Quadrangle, Iowa. — How is this quadrangle located with respect to the Lancaster Quadrangle? Would you describe the divides as broad or narrow? Are they distinct or indistinct? High or low? How do they compare in these respects with the Lancaster and Portage areas? Is the run-off good or poor? Is the region well drained? How does the number of tributaries compare with that of the other areas? Are the valley sides steep? Do they vary in

this respect? Do the valleys vary in width? Most of these variations are due to deflection by ice work. For example, does the Maquoketa below Monticello follow a usual behavior? The river is believed to have flowed through the Scotch Grove region, southeast of Monticello. Does a map study corroborate this belief? This region is overlaid by drift older than that of the Portage region.

Résumé.—In the Lancaster county we have a region not glaciated; in the Portage region the country is overlaid by young drift of the last glacial period; in the Anamosa region the country is overlaid by drift older than that of the Portage region (probably of Iowan age). We have a good opportunity to compare a topography developed by subaërial erosion, one by recent glaciation, and one by older glaciation and subsequent stream work. Compare carefully their dissection (stage, shapes of valleys, uplands, divides), their stream profiles, tributaries, run-off, and completeness of drainage. Draw type examples from each locality.

Glaciated and Unglaciated Regions. Raritan Quadrangle, New Jersey.—From the drainage conditions, determine approximately the glaciated and the unglaciated portions of this quadrangle.

Give reasons for your answers.

CHAPTER XIII

LAKES

*130. OXBOW LAKE

Elk Point Quadrangle, South Dakota-Nebraska-Iowa. —To what class does McCook Lake belong? What other example? Has it an inlet? An outlet? Why does it not dry up? What is the origin of this class of lakes? Where are others likely to be formed?

*131. LAKES AND SWAMPS ON A FLOOD PLAIN

Marysville Quadrangle, California. — Review Exercise 57. What do the swamps and lakes on either side of the Sacramento River indicate, high or low land? Give reasons for your answer. What is the origin of Butte Slough and Long Lake? Do you think these lakes are deep or shallow?

132. DELTA LAKES

East Delta Quadrangle, Louisiana. — Review Exercise 59. Which do you think first existed, Jackass Bay or the passes north and south of the lake? Was the lake formerly larger or smaller than at present? Is it likely to increase or decrease in area? Why?

What is the origin of the lake? May Blind Bay ever become a lake? If so, how?

133. LAKES IN ROCK BASINS

Gilbert Peak Quadrangle, Utah – Wyoming. — Review Exercise 116. Are cirques due primarily to ice erosion or ice deposition? Would you expect the bottoms of cirques to be of drift or of solid rock? What is the origin of most of the lakes, such as Fish Lake?

*134. AN ICE-BLOCKED VALLEY

Mount Marcy Quadrangle, New York. — What is the general elevation of the upland? How far beneath this elevation are the upper and lower Ausable Lakes? How wide is the valley of lower Ausable Lake? How wide is the lake? This valley is thought to be a preglacial valley, subsequently eroded by ice and later blocked by drift. How does the valley resemble a normal erosion valley? An ice-eroded valley?

*135. MORAINIC LAKES

Whitewater Quadrangle, Wisconsin.— Review Exercise 118. What is the principal agent that has fashioned the topography of this region? Trace the principal moraine. How many lakes are there on the moraine? Are there any depressions that do not contain water? Are there any depressions that are only

partly filled? Do most of these morainal lakes have inlets? Outlets? How do they get their water? What becomes of their water? Roundish morainic lakes in a moraine are called "kettle lakes." Are the lakes near Palmyra and Whitewater kettle lakes?

136. AN EXTINCT MARGINAL GLACIAL LAKE

Passaic, N.J.–N.Y., and Raritan, N.J., Quadrangles. —Beginning at Paterson, note the valley of the Passaic River. How wide is the valley? Where does the Passaic head? Where does it empty? Does it take a direct course to its outlet? Are the swamps in its upper or lower course? Is this the normal location of swamps? Where does the basin, in which the valley lies, end? What are the boundaries of this valley? How high are the Watchung ridges? Where are there notches in these ridges? How low are these notches below the crests of the ridges?

In the preglacial times the Passaic is thought to have crossed the ridges near Short Hills. During the glacial period the ice occupied the Passaic basin. When the ice front had retreated northeast of the Second Watchung, a marginal lake was formed. Why? Where would be its main outlet? Into what river would this outlet flow? At this time, how deep was the water at Liberty Corner (about seven miles north of Somerville)?

When the ice margin reached the vicinity of Madison

and Chatham, it halted and built a moraine. Trace this moraine. What morainal characteristics has it? What effect would it have on the Short Hills outlet? From here the ice front retreated until the gap at Paterson was passed. What effect would this exposure of the gap have on Lake Passaic?

After the water of Lake Passaic had mostly disappeared, the depressions in the lake bed were still filled with water (consequent lakes). Great Piece Meadows and Great Swamp are sites of two of these lakes. Why should these sites still be swamps? Make a sketch showing the borders of Lake Passaic, the first outlet near Far Hills (eight miles north of Somerville), the moraine built during the ice retreat, and the final outlet at Paterson.

What effects have these swamps on the life of the inhabitants? Where are the swamps being drained? What uses are made of the moraine near Short Hills? Why is there a falls at Paterson? What geographic factors in the location of Paterson?

REFERENCE. — An excellent account of Lake Passaic is given by Professor R. D. Salisbury in Chap. 5, Vol. 5, "Glacial Geology of New Jersey," Final Report, 1902.

137. A CRATER LAKE

Crater Lake Special, Oregon. — In what part of Oregon is Crater Lake? Of what range of mountains

is it a part? What is the average diameter of the lake? How high is the water surface above sea level? What is the average depth of the water surface below the surrounding cliffs? What is the average depth of the lake?

Make a profile from the Watchman west to the margin of the map and from Sentinel Rock east to the base of Scott's Peak. How do the outer slopes of Mount Mazama compare with the slopes toward the lake? Continue your profiles until they meet. Their intersection represents roughly the former height of the mountain. How high above the present Mount Mazama is this intersection? How do the slopes of the lake bottom off the Palisades (northeast shore) compare with the southwestern slopes of the Palisades?

Read the description on the back of the map. What is the probable origin of Crater Lake? What significance with this origin have (*a*) the outer and the inner slopes of Mount Mazama, (*b*) the slopes of the lake bottom, (*c*) the inlets and outlets, if any, of Crater Lake? What significance in the radial arrangement of the valleys on the mountain side and their upper termination?

Compare this lake in the above-named features with the lakes previously studied. Which types of lakes does it most resemble?

Compare Mount Mazama with Mount Shasta as to

lava-flows, coulees, dissection, and slopes. Compare it with Marysville Buttes as to dissection.

138. CONSEQUENT AND SOLUTION LAKES

Arredono Quadrangle, Florida.—How does this surface compare with a glaciated surface, *e.g.* the Whitewater, Wis., region? In what stage of erosion is the region? About what percentage of the surface is covered with water? Do you think the lakes are shallow or deep? Do they have outlets? Inlets? Are the lakes variable in area? How far above sea level are most of them?

The surface of Florida is youthful geologically and largely underlaid by very soluble rocks. The lakes are probably in part consequent, and in part due to solution.

139. LAKES DUE TO FAULTING

Alturas, Cal., and Long Valley, Nev., Quadrangles.—Review Exercise 106. What is the origin of Upper Lake, Middle Alkali Lake, and Lower Lake? Why are they nearly in a straight line? Do they have an outlet? Why? Why are their waters alkaline?

Find lakes of similar origin on the Long Valley Quadrangle. Do these lakes appear to have a constant volume? Give reasons for your answer.

140. A NEARLY DRAINED LAKE

Sierraville Quadrangle, California. — Sierra Valley was once occupied by a lake. What is the area of this valley? What was the outlet of the lake? By what two agencies was the former lake drained? How deep is the Feather River Valley below the general level of the upland? Which part of the lake bed is best drained? What topographic forms were the "buttes" when a lake occupied the valley? Do you think that the former lake shore was smooth or indented? Why is the present bottom of the Sierra Valley smoother than the uplands? Which would make the best agricultural lands? (Give several reasons.)

*141. LAKES AS FILTERS

Charts of Lake Ontario and Lake Erie. — Which river, the Niagara or the Maumee, do you think has the greatest volume? Why? How large an area has the delta at the western end of Lake Erie? Is there a similar delta at the mouth of the Niagara? Is the volume of the Niagara River about equal to the combined volumes of the streams entering the western end of Lake Erie? How would you explain the contrast in their deltas?

CHAPTER XIV

THE OCEAN

•142. DEPTHS OF THE ATLANTIC ALONG THE PARALLEL OF 40°, FROM NORTH AMERICA TO EUROPE

U. S.	15 miles	19 fathoms	2100 miles	1130 fathoms
	125 miles	40 fathoms	2150 miles	609 fathoms
	250 miles	1460 fathoms	2250 miles	1200 fathoms
	500 miles	2800 fathoms	2500 miles	2360 fathoms
	1000 miles	2930 fathoms	2750 miles	2650 fathoms
	1500 miles	2675 fathoms	3125 miles	2090 fathoms
	1750 miles	2600 fathoms	3190 miles	60 fathoms
	2050 miles	1230 fathoms	3230 miles	Land (Europe)

MAKE a profile of the bed of the Atlantic. Allow one inch to represent 100 miles and a small square to represent 100 fathoms. Leave margins at the sides of the sheet so the sheets may be pasted together.

What State does the parallel of 40° touch? What country in Europe? Which part of the profile shows the least relief of the ocean bed? Where is the greatest depth in the profile along the fortieth parallel? How many miles is it from America? From Europe? Locate the platform on which are the Azores. About how far from both coasts are the continental slopes? Which

continent has the wider shelf? What is approximately the average depth of the Atlantic along the parallel of 40°?

*143. THE CONTINENTAL SHELF

Coast Chart No. 1007, *The Gulf of Mexico and Straits of Florida.* — What is the scale of this map? Make a generalized profile along the line of soundings north of Cape Canaveral from the coast to the eastern edge of the map. (Use 100-fathom contour interval.) Where is the steepest slope? What is the average slope per mile here? Where is the edge of the continental shelf? What is the average slope of the continental shelf from the coast to its edge? From the edge of the continental shelf to its base?

Coast Chart No. 5300, *Santa Rosa Island to Point Buchon, Cal.* — In what part of California is this region? Make a profile along the line of soundings in the middle of the chart. Compare it with the profile of the continental shelf of the Atlantic coast.

*144. DAILY TIDES

Plot the tidal curve for Boston. Along the longer edge of the paper, number each small square for each hour, beginning at midnight. Along the shorter edge, allow each large square to represent one foot. Write the dates of the month above the squares in their appro-

priate places. The minus numbers indicate tides below the mean sea level.

TIDE TABLE FOR JANUARY 1 to 4, 1909. BOSTON, MASS.

Jan. 1	6.45 A.M.	9.7	Jan. 3	2.27 A.M.	0.3
	1.10 P.M.	0.1		8.40 A.M.	10.1
	7.20 P.M.	8.9		3.08 P.M.	−0.3
				9.21 P.M.	8.8
Jan. 2	1.30 A.M.	0.3			
	7.44 A.M.	9.9	Jan. 4	3.20 A.M.	0.3
	2.11 P.M.	−0.1		9.32 A.M.	10.3
	8.22 P.M.	8.8		4.00 P.M.	−0.5
				10.13 P.M.	8.8

Are the high tides of the same height? Are the low tides? What is the average tidal range? How many high tides, in the average, in each day? How many low tides? Do the high and low tides occur at a corresponding hour each day? What is the average difference in time between high tides for the above dates? Between low tides? How much later, on the average, does the tide rise each succeeding day? Why is it that the hour for sea bathing at many resorts changes from day to day? Why do ships often leave or enter harbor late at night?

*145. DAILY HIGH TIDES

Plot the curve of highest tides. When are the tides highest? When lowest? How many maxima in a month? How many minima?

TABLE GIVING THE HIGHEST TIDES ON EACH DAY AT SANDY HOOK, N.J., JANUARY 1 TO JANUARY 31, 1909

Jan. 1	4.8	Jan. 9	4.8	Jan. 17	4.5	Jan. 25	5.3
2	4.9	10	4.5	18	4.8	26	5.0
3	5.1	11	4.3	19	5.1	27	4.7
4	5.2	12	4.0	20	5.3	28	4.8
5	5.3	13	4.0	21	5.5	29	4.8
6	5.3	14	4.0	22	5.7	30	4.7
7	5.2	15	4.1	23	5.6	31	4.7
8	5.0	16	4.2	24	5.5		

The moon is full January 6, and new January 21. The third quarter comes January 14, and the first quarter January 28. Place the following symbols above your curve: for the new moon ●; the full moon ○; the first quarter ☽; the third quarter ☾.

With what phases of the moon do the maxima and minima of the tides approximately coincide? Draw diagrams showing the positions of the earth and moon at each phase. Explain your curve. Label your tidal curve at the proper places "spring tides" and "neap tides."

146. TIDES ON A SMOOTH AND AN INDENTED COAST

Locate Bath and Sandy Hook (Bath, Me., and Navesink, N.J., Quadrangles). How do the coasts compare in smoothness?

Plot the tides for Bath and Sandy Hook. (Use the

same method as in Exercise 144.) Which place has the highest tides? Explain the differences in view of the different coast lines.

Bath, Me.		Tide	Sandy Hook, N.J.		Tide
Jan. 1	12.01 A.M.	0.7	Jan. 1	3.08 A.M.	4.8
	6.19 A.M.	6.3		9.34 A.M.	0.3
	12.41 P.M.	−0.7		3.40 P.M.	4.2
	6.56 P.M.	6.0		9.44 P.M.	0.0
Jan. 2	12.02 A.M.	0.2	Jan. 2	4.05 A.M.	4.9
	7.17 A.M.	6.5		10.35 A.M.	0.2
	1.44 P.M.	−0.2		4.40 P.M.	4.2
	8.00 P.M.	5.9		10.40 P.M.	0.0

Compare the times of high and low tides at the two places.

147. LAGGING OF THE TIDES

THE AVERAGE TIME OF HIGH WATER AFTER THE MOON'S TRANSIT IS GIVEN IN THE FOLLOWING TABLE

Honolulu	6 hr.	48 min.
Apia (Samoan Is.)	6 hr.	25 min.
St. Helena	3 hr.	00 min.
Canary Is.	1 hr.	15 min.
Liverpool	10 hr.	56 min.
Bath, Me.	12 hr.	13 min.
Boston, Mass.	11 hr.	28 min.

Locate all of these places on a map or globe. Which are continental? Which insular? Which ports have the greatest lagging? Explain your answer.

148. TIDAL CURRENTS

TIDE TABLES FOR JANUARY 1 AT WILLETS POINT AND GOVERNORS ISLAND

WILLETS POINT	TIDE	GOVERNORS ISLAND	TIDE
12.25 A.M.	0.3	3.40 A.M.	4.5
6.36 A.M.	7.5	10.15 A.M.	0.1
1.30 P.M.	0.2	4.00 P.M.	4.0
7.15 P.M.	6.7	10.22 P.M.	-0.2

Locate Willets Point, Governors Island, and Sandy Hook on Chart No. 120, New York Bay and Harbor. Plot the tidal curves for these places. What is the body of water connecting these places? How long is it? What is the tidal phase at the two places 12.25 A.M.? At 6.36 A.M.? At 1.30 P.M.? At 7.15 P.M.? Which way will the tidal currents move at each of these times? From your curve determine what relations of tidal phases about 11 A.M. and 3 P.M.

What configuration of the coast favors these currents? What effect have they on the channel? Why is Hell Gate somewhat dangerous for navigation?

*149. OCEANIC AND COASTAL TIDES

Plot on the same sheet the curves for Honolulu and San Francisco. (Use half squares on the longer lines for hours, and the small squares on the shorter lines for

tenths of a foot.) What is the greatest range for each place? What is the average range for each place?

HONOLULU AND SAN FRANCISCO

Honolulu		Tide	San Francisco		Tide
Jan. 1	12.22 P.M.	1.5	Jan. 1	12.28 A.M.	1.9
	7.07 A.M.	0.4		7.10 A.M.	5.8
	11.45 A.M.	0.8		1.56 P.M.	0.7
	5.37 A.M.	−0.1		8.45 P.M.	4.2
Jan. 2	1.07 A.M.	1.8	Jan. 2	1.22 A.M.	2.4
	8.17 A.M.	0.3		7.52 A.M.	6.0
	12.46 P.M.	0.7		2.52 P.M.	0.0
	6.22 P.M.	−0.1		9.52 P.M.	4.3

Locate the two cities on a globe. Explain the difference in their ranges.

*150. OCEAN CURRENTS

From a good map, make a sketch map of the principal ocean currents, noting their positions, directions, and widths.

From pilot charts of the North Atlantic Ocean and the North Pacific Ocean, sketch the currents shown.

THE GULF STREAM

Coast Chart No. 1007, *Gulf of Mexico* — See "Gulf Stream Currents." Is the velocity constant or variable? What is the average velocity in the Yucatan Channel? South of Rebecca Shoal? East of Cape Florida?

151. AN ATOLL

Funafuti Atoll. Chart No. 1802, *Hydrographic Office.* — What is the scale of this map? What is the average depth of water two miles from the land? One mile? Is the slope from land to sea bottom steep? How does it compare in steepness with the steep part of the continental shelf (Exercise 143)? With the coast of New Jersey (see Chart No. 121)? So far as it is shown, by what is the sea bottom covered?

About how long is the rim of land? About what average width? Is it continuous? About how high is the rim? Is it, as a rule, bare or wooded? Of what do you think it is composed? How is it built up so high above sea level? What causes the openings in the rim? What openings are suitable for vessels?

What would you say is the average depth of water within the rim? Is the bottom level? Is it more or less level than the sea bottoms you have previously studied? Is the slope from the reef within greater or less than from the reef seaward?

About how high above the general level of the sea bottom is the bottom within the atoll? Do you think there is much animal life on the land? Of what is the sea bottom within the atoll mainly composed? What is the latitude and longitude of Funafuti Island? What direction from San Francisco? About how far?

*152. CORAL REEFS

Coast Charts No. 1007, *Gulf of Mexico; No.* 169, *Newfoundland Harbor Key to Boca Grande Key.* — On the large chart, you will note the line of coral-built structures extending from Florida westward. How long is this line of reefs and keys? About how wide? What similar formations along the coast of Cuba? Along Great Bahama Island? From how deep water do they rise along the straits of Florida? Do they rise suddenly or gradually? Do the Florida reefs continue northward beyond the Gulf Stream? What reasons can you give? (Shaler states that the reefs begin at about 27° north latitude.)

Chart No. 169 shows a portion of the reefs. What portion? What are the parts of the reefs above water called? How would you account for the bodies of water in the keys west of Key West? Why is the sea bottom mostly covered with white sand?

Chart of the Hydrographic Office, No. 1850, *Harbor of Apra, Island of Guam.* What part of the reef north of the harbor is above water? How long is the Luminan Reef and its extension, Calalan Bank? How wide is the 6-foot reef on the south side of the harbor? (See explanation in the lower left-hand corner of the chart.) How wide is the 18-foot reef here? Is the shore behind the reef steep or shelving? How high is

val, sketch an area three miles square here, and an equal area on the land to the westward. Compare your sketches.

Provincetown and Wellfleet Quadrangles, Massachusetts. Coast Chart No. 110, *Cape Cod Bay.* — Make sketches about four miles square, using a contour interval of 20 feet, of the following areas: The township of Truro (Provincetown quadrangle) and the sea bottom immediately adjacent on the east, or a portion of the same township in the northern part of the Wellfleet Quadrangle with the sea bottom on the east.

154. A YOUNG COAST

*PART I. *Boothbay Quadrangle, Maine.* — How far, and in what direction, is this region from Portland? From Boston? How long would the coast line be if it extended in a straight line from Pemaquid Point to Griffith Head? How long is the coast line? (Let members of the class measure the following portions of the coast line according to the method in Exercise 65: Pemaquid Point to Crow Island; Crow Island to Peter Island; Carlisle Point to Ocean Point; Ocean Point to Spruce Point; Spruce Point to Cape Newagen; Cape Newagen to Quarry Point; Quarry Point to Griffith Head.)

Do you think the coast has been much eroded? Do you find bars or spits? What explanation would you

give to your answer? Does this mean that it is older or younger in age? Will the coast become smoother or more indented as erosion continues?

PART II. *New London Quadrangle, Connecticut. Coast Chart of the Thames River and the Harbor of New London, No.* 359. — Was this coast at first as much indented as the Maine coast? Has it been the more or the less smoothed than the Boothbay coast? What does the truncated appearance of Bluff Point and Black Point suggest? What bearing on this question have the spits on the western sides of these points? How deep is the water back of Bushy Point Beach? Do you think that the marsh is being filled by the river or by the sea? What bearing on your answer have the numerous lakes along Poquonoc River? Do the spits have any general direction from their origin? What explanation? How can you account for the ponds north of Groton Long Point?

Is this coast at an earlier or a later stage than the Boothbay coast? Does this mean that it is older or younger in age? Sketch good types to illustrate your answers.

*155. OFF-SHORE BARS

Atlantic City Quadrangle, New Jersey. — How far, and in what direction, is this region from New York? From Philadelphia? About how far is it from the beach to the mainland? How wide is Brigantine Beach?

Island Beach? How high are these beaches above sea level? Are they connected with the mainland? Other things being equal, as time goes on, are they the more or the less likely to be connected with the mainland? Are Brigantine Beach and Island Beach bars or spits? What is the distinction between bars and spits? What do you think the small mounds on the beaches are? Which is the smoother shore of the beaches, the outer or the inner? Explain your answer. Are the bars continuous or broken? Why are they so? Which way do the "hooks" at the ends of the bars generally point? How wide is the area of marshy land (the lagoon)? About what proportion of it is marsh, and what water? Do you think that the marsh was formed *before* or *after* the bars? Why? If the bars were removed, would the marsh land be affected? What part of the lagoon is drained artificially? How has the lagoon probably been filled? How high is the mainland on the average? Does it slope to the shore gently or abruptly? What is the slope per mile from Centerville to the marsh? Make a profile from Smithville through Leeds Point to the marsh. On this profile, what is the slope of the mainland to the cliff? What is the slope of the cliff?

Would you describe the meeting of the land and marsh as straight or crooked? How far northwest or southeast from a straight line would this line of meet-

ing swerve? How does it compare with the meeting of land and water on the Boothbay, Me., and the Temalpais, Cal., quadrangles? How does it compare with the inner and outer shore of Brigantine Beach? What agency could have cut the cliff and smoothed the shore here?

Which was first made, and in what order, the bar, the lagoon, or the cliff on the mainland? How many railroads lead to Atlantic City. Does the bar offer facilities for commerce? For manufactories? Account for the growth of Atlantic City. What means of communication are there between the bars and the mainland? If Coast Chart No. 123, Absecon Inlet to Cape May, is at hand, note the following points: Is the ocean bottom off Atlantic City steep or shelving? What is its slope per mile for the first mile? For the first six miles? What relation has this fact to the formation of bars? How deep is the lagoon south of Atlantic City? Is Egg Harbor Inlet larger or smaller than the average inlet? How would you explain your answer? Is this coast in an older or a younger stage than that of the Boothbay, Me., coast?

156. SEA CLIFFS AND WING SPITS

Navesink Quadrangle, New Jersey–New York. Coast Chart No. 121, *Sandy Hook to Barnegat Inlet.* — What are the scales of the two maps? How long is

Sandy Hook from Hook Beacon to Highland Beach? How long is it, in inches, on each map? Is the coast, as a whole, smooth or rugged? High or low? Where is the sea cutting? Where is its building? Where are there cliffs? How high are they? Where are there spits? How high are they? How broad? How high is the cliff from Long Branch to Point Pleasant? How long? Is the sea cutting or building this cliff? In general, is the detritus from this cliff deposited eastward from the cliff by the undertow (see the coast survey chart)? How do you know? If the detritus is not carried *eastward* from the cliff, where must it be carried? Is it carried by currents *normal* to the shore or *longitudinal* with the shore? What wind direction would produce shore currents flowing northward? Southward? How do these facts explain the cliff with its attached spits on the north and south? (Such a cliff with its attached spits has been called a cliff with wing spits.) Do you think that the coast from Long Branch to Point Pleasant has always been so even? If the bars before Metedeconk Neck and the unnamed peninsula to the north were removed so that the waves could attack them, would the coast line be the more or the less straightened? Would it the more or the less resemble the Long Branch stretch of coast?

Does the spit beginning at Bayhead continue southward unbroken? Why? Where are the inlets,

in general, located? How long is the spit which ends in Sandy Hook? Why is it so narrow opposite Shrewsbury and Navesink rivers? Why does this spit turn and become a "hook" at its northern part? What strategic value has Sandy Hook? How is it utilized?

Would you describe the shore line back of the spits as smooth or indented? Does it indicate a stationary, risen, or sunken coast? Why? Which is the older, in years, the indented shore line back of the spits, or the spits? What evidence on the Highlands of Navesink and Rumson Neck of former wave action? As the cliff coast is cut back by the waves, will the wing spits on either side remain stationary, advance, or retreat? Why? What is the average depth of the dotted area east of the coast (from the chart)? The average width? Is there a similar zone in the Atlantic City region? Is it as uniform in width and as smooth? Is the slope between the dotted area and the undotted area gentle or abrupt? How would you account for this abrupt slope?

How far apart are the life-saving stations? Why are so many necessary? Are the light-houses uniformly grouped along the coast? Why? How high are the Navesink lights? How far are they visible in clear weather? The Hudson formerly had its mouth far to the eastward. How is its old channel indicated

by the 30-fathom curve? What coastal movement is indicated by this fact? Why does the 30-fathom curve disappear near land? You have on these maps examples of a shelving coast, a drowned coast, a cliff coast with wing spits derived from it, spits, hook, lagoon. Sketch an example of each.

REFERENCE. — This class of shore lines is described by Tarr, "Physical Geography of New York," Chapter X.

157. TIED ISLANDS

Boston Bay Quadrangle, Massachusetts. Coast Chart of Boston Harbor, No. 337. — Nahant and Little Nahant are composed largely of hard, crystalline rock. How are they connected to the land? How high are Nahant, Little Nahant, and Lynn Beach? Which have the more rugged outlines? Which outlines suggest *constructive* work by the sea and which *destructive* work? What bearing on this question have the altitudes of the localities? How long is Lynn Beach? How wide? Is Lynn Beach a narrow ridge with steep side slopes, or is it a small area above water of much wider spit (see the chart)? Which of these features, the Nahants or Lynn Beach, suggest wave work? Which work by currents? How? What do you think Lynn Beach is made of? Why? Find several other good examples of tied islands, and sketch the best example. Where are there cliffs on

Deer Island, Long Island, Brewster Islands, Great Hill, Sagamore Head? What do you think made the cliffs? Do they for the most part face the same direction? What does this fact suggest, and how would you explain it? From the chart, would you think that there are more spits and bars in Boston Harbor than the *quadrangle* shows? Why is dredging in the approaches to Boston necessary? Are there any strong rivers entering Boston Harbor?

Problem: Nantasket Beach.

Great Hill, Strawberry Hill, and Sagamore Head are drumlins. Are all their slopes equal? Why do their cliffs face the same direction?

What agent is making the cliff at Great Hill and Surfside? Do you think the same agent made the cliff on Strawberry Hill and White Head? Are the waves now eroding Strawberry Hill? How far from the water is the wave-cut cliff on Strawberry Hill now? Why are the waves not cutting Strawberry Hill now? What possible sources for the material which has been deposited in front of Strawberry Hill?

158. SHORE LINES OF EXTINCT LAKES

Berea Quadrangle, Ohio.—Taking the region as a whole, is there a high area and a lower area? What general altitude has the higher area? The lower area? Are the areas separated by an escarpment? Is it steep?

What is its average slope per mile? How does it compare with the Niagara escarpment?

The lower region was covered by the waters of several glacial lakes, among them Lakes Maumee, Whittlesey, and Warren, which stood at different levels and made beaches at those levels. How high was the water when Butternut Ridge was made? Chestnut Ridge? Middle Ridge? North Ridge? Draw a profile from Olmsted Falls to West Dover. Do the ridges have equal slopes on each side? Is there a plain back of each ridge? In general, are the ridges small escarpments? Do you think that they were caused by wave cutting or by wave building? Why? How much, in each case, did the water surface fall before cutting a new beach? Do you think the water surface fell uniformly? Why? What do you think was the reason that the water surface would fall rapidly and then become fairly stationary?

What is the general trend of the ridges? Are they parallel? What influence have they on roads? Why? What kind of soil would you expect them to have, clay, sand, or gravel? Do you think that the valley of Rocky River was cut before or after the formation of these ridges? Why?

Which is the more dissected, the lake plain or the plateau (Alleghany Plateau)? How would the greater altitude of the plateau come in as a factor in your

answer? The duration of exposure? The hardness of materials? At present, what are the waves of Lake Erie doing, cutting or building? How high are the cliffs along the lake? Are they much dissected? What is the altitude of Lake Erie?

REFERENCE. — "Drainage Features of the Erie and Ohio Basins," by Frank Leverett, Monograph 41, U.S.G.S.; especially Chapters 14, 15, 16.

*159. A RISEN COAST

San Luis Quadrangle, California. — In what part of the state is this region? How far, and in what direction, from San Francisco? From Los Angeles? In general, along the Pacific coast there has been an elevation of the land together with folding. The folding was, in general, parallel to the coast. Subsequently there was a slight depression. What is the direction of the mountain ranges? Are they parallel? What is the general direction of the trend of the coast? What is the general height of the coast between San Luis Obispo Bay and Morro Bay? North of Morro Bay? South of San Luis Obispo Bay?

Compare the Atlantic City, N.J., coast with this in height and smoothness. They are both risen coasts with slight subsequent depression. How would you explain the differences? If the folding in the San Luis region had been perpendicular instead of parallel to the shore,

how would the coast probably be different? Sketch good examples, showing the differences in the two coasts. Is the coast in the vicinity of Morro Bay cut or built? By what is the spit west of Morro Bay covered? The sand has drifted up the sides of the northern end of San Luis Mountains for about 700 feet. How are the sand slopes different from the other mountain slopes? Why?

160. A YOUNG RISEN COAST WITH A NARROW COASTAL PLAIN

Nome Special Map, Alaska. — This coast has been elevated so as to expose a small line of lowland, probably, in part, a former sea bottom. How high is the upland? How high is the coastal plain at its inner margin? How does this coast differ from the San Luis, Cal., region? Both this coast and the Atlantic City, N.J., coast are low, shelving coasts. Which of these two is the older in stage of coastal erosion? Assuming that there is no further elevation or depression, how will this coast change? Will it the more or the less resemble the Atlantic City coast? Why is it so difficult and dangerous to land at Nome during rough weather?

161. ELEVATED WAVE-CUT TERRACES AND CLIFFS

Coast Chart No. 5100, *Pacific Coast from San Diego to Santa Monica.* San Clemente Island. — How far, and

in what direction, from San Diego? This island has been elevated several hundred feet. How many terraces on the southern coast? Do these terraces indicate a continual uplift or an intermittent uplift? What ocean factors produced the terraces? How wide are the various terraces? How high on the average is the island above sea level? Above the general level of the ocean bottom?

San Clemente Island is thought to be an elevated and tilted fault block. What evidences are there? What similarities in the fault block shown on the Alturas, Cal., Quadrangle? In what direction was the tilting? How high is the fault scarp above sea level? How do the soundings on opposite sides of the island compare, and how do they support the idea of a fault block?

REFERENCES. — San Clemente Island is described by A. C. Lawson in Bulletin of the Department of Geology, University of California, Vol. I, No. 4; also by W. S. T. Smith, 18th An. Rept. U.S.G.S., Part II.

162. A TIDAL DELTA

Coast Chart No. 5532, *San Francisco Entrance.* — What rivers enter San Francisco Bay? Where do you think they drop most of their sediment, in the bay or in the Pacific? The average rise and fall of the tide is about four feet. Would the incoming tide bring much sediment? Would the outgoing tide? Why? What evidence of the sediment carried by the outgoing tide is to

be seen west of Golden Gate? About what is the radius of the tidal delta? Is the water deepest at the Golden Gate or several miles to the west? How would you explain your answer? How does the shape of this delta compare with that of the Mississippi delta? How would you explain their difference? What is the area of the delta? How many ship channels cross it?

163. GENERAL EXERCISE

Wellfleet and Provincetown Quadrangles, Massachusetts. Coast Chart No. 110, *Cape Cod Bay.* — Note the scales of the chart and the quadrangles. How long is Cape Cod from the "elbow" up? What average width? Contrast in *all* respects the eastern and the western shores. Which shore is due largely to destructive action? What are the predominant agents in this action? Which shore is due largely to constructive action? What are the predominant agents?

Where is Cape Cod highest? Where lowest? As the mainland in Truro Township retreats westward, what change will take place in Salt Meadow and the pond to the westward? How will this change affect Provincetown Harbor? How will such a retreat affect the position of the spits south of Truro and Wellfleet townships?

What factors make a harbor at Provincetown? What is its average depth? Why are there so few good har-

bors on the eastern coast? Are the islands making the series ending in Billingsgate Island disconnected, or are they the portions of a feature having some of its parts above water? Is Billingsgate Island likely to be connected with Great Beach Hill? Explain your answer. How deep is Wellfleet Harbor? Is it likely to become deeper or shallower? Why?

How wide is the platform of wave and current wash on the eastern coast? Make a generalized profile from Highlands Life-saving Station about one and a half miles seaward. Is the slope between the platform and the sea bottom farther out gentle or abrupt? Why? How wide, in general, is the submarine platform on the western shore? Which would favor a wide submarine platform, strong or weak longitudinal shore currents? What inference can you make as to the strength of waves on the eastern and the western coasts? Sketch good examples of spits, hooks, wave-cut cliffs, cliffs and associated wing spits, submarine platform, tied island, lagoon, tidal inlet, smoothed coast, built coast. (Many can be included in one sketch.)

Hampton Quadrangle, Virginia. — To what coast that you have studied is this most similar? Is it a youthful, mature, or old coast? Where is there a feature similar to the Long Branch, N.J., coast?

Islip Quadrangle, New York. — From what you have learned, discuss Fire Island Beach, Oak Island Beach,

and Jones Beach; the shore north of Great South Bay and the north shore of Long Island. What significant contrast between the two shores? Would you consider Great South Bay a lagoon? Is it in part filled? Note all the shore forms you can.

CHAPTER XVI

HARBORS

*164. HARBORS. INTRODUCTION

THE following points are important in determining the value of a harbor: —

1. Communication with the back country or the hinterland (by road, railroad, or water).
2. Deep anchorage.
3. Deep channel from the anchorage to the sea.
4. Protection from winds.
5. Protection from high waves.
6. Area of the anchorage.
7. Length of shore line.
8. Absence of strong tidal currents.
9. Deep water near the shore.
10. Possibility of fortification.
11. Freedom from bars, especially shifting bars.
12. Freedom from ice.

State fully and specifically in what respects you think these factors are of advantage. What significance has the twelfth factor with respect to Russia? Study each harbor with respect to these factors.

*165. A DROWNED VALLEY HARBOR. NEW YORK HARBOR

Coast Chart No. 120, *New York Bay and Harbor*.

The Lower Bay. — Is there a single entrance? How many? What is the average depth of water? What is the average depth of the various channels? Which channel will accommodate the larger boats?

The Narrows. — How wide? What is the average depth? What reasons can you give why the Narrows are so deep? What facilities for fortification here? How are they utilized?

The Upper Bay. — How wide is the channel that is five fathoms deep or over? How far from the Narrows up to the city? How many square miles of water here over five fathoms in depth? How long a water front has New York? Brooklyn? Jersey City? What is the combined length? Is the water deep near the shore? How high is the average tide at Sandy Hook? Governors Island? Willets Point (on Long Island east of Whitestone)? What features make New York Harbor one of the best in the world? How many of the desirable features outlined in the opening paragraph has it? Would the Galveston hurricane produce so disastrous results here? Vessels, so far as possible, avoid Hell Gate. Why?

*166. A RIVER HARBOR. NEW ORLEANS

New Orleans Quadrangle, Louisiana. Coast Charts No. 1007, *Gulf of Mexico; No.* 194, *Mississippi River from the Passes to Grand Prairie; No.* 195, *Mississippi River from Grand Prairie to New Orleans.* — How does the smoothness of the coast in the vicinity of the Mississippi compare with the rest of the Gulf coast? Does the coast project near the Mississippi? Why? How much does it project?

The Delta. — What is its shape? Explain its shape. What is the average rise and fall of tide? What bearing has this on the shape of the delta? Would you infer that there are strong shore currents? Why? Which of the three main distributaries has the greatest average depth of water? What is its average depth? Which pass is inclosed by jetties? What use have these jetties? Do you think they will ever have to be lengthened? Why? How are vessels guided to the mouth of the pass? Would any of the bays or sounds, such as Bird Island Sound, make good harbors? Why? Why could not a city be built on the delta itself? Why is a city in this region a commercial necessity?

Coast Charts Nos. 194, 195. — How far is New Orleans from the ends of the jetties? What is the average depth of water up to the city? The average width of navigable water?

The Topographic Map. — What is the general altitude of the city as shown by the contours? Which way does the land slope? Why? What advantages has this harbor? What disadvantages?

*167. A MORAINE HARBOR

Boston, Mass. Boston and Boston Bay Quadrangles, Massachusetts. Coast Chart No. 337, *Boston Harbor.* — Boston Harbor is made by a slightly drowned valley and by glacial deposits (many of them drumlins) to seaward.

Is there a single approach? Why? Which channel is the deepest? How long is the available water front at Boston? What draught of vessel could not enter the harbor? What facilities for fortification? For construction of lighthouses? For wind protection from the east? From the west? Do you think that easterly winds would bring high waves to the harbor? Why? How long is the principal channel from the harbor to the open sea? Do you think there is much silt and sand brought from the mainland? Which of the factors enumerated in the opening paragraph has Boston Harbor? Which does it lack?

*168. A BAR HARBOR

Coast Charts, Gulf of Mexico, No. 1007, *and Galveston Bay, No.* 204. — The coast of Texas is a low, shelv-

ing coastal plain which has not been depressed to the same extent as the coastal plain farther north. From the chart of the Gulf of Mexico, determine whether Texas, Mexico, and Yucatan have smooth or indented coasts. How do they compare in this respect with the eastern coast of the United States? Explain the contrast. How does this coast compare with the Maine coast? Are there off-shore bars? How long is the line of bars? How many inlets from Galveston to Point Isabel? How many miles of bars on the average to each inlet? How does this compare with the New Jersey coast? Does this number of inlets indicate strong or weak tides? Under such conditions, are harbors plentiful? Why? What determines the harbors? Do you think such harbors are good ones?

Galveston Harbor. — How wide is the bar on which the city is built? How wide is the inlet? How deep is Bolivar Channel? How long are the jetties on either side? Of what use are they? How deep is the dredged channel along the city front? How deep is Galveston Bay? Is it suitable for a harbor?

Which of the factors enumerated in the opening paragraph are favorable to Galveston? Which, unfavorable? Which of these factors made the hurricane of 1900 so destructive? What steps have been taken to prevent a recurrence of such a disaster (see current magazines)?

*169. SAN FRANCISCO HARBOR

Coast Charts, No. 5500, *Pacific Coast from Point Pinos to Bodega Head; No.* 5532, *San Francisco Entrance.* — How much of the coast is shown in the small scale chart? Is it a markedly indented coast? How does it compare with the Atlantic coast? From a general map, determine the number of harbor cities on the Pacific coast. How does it compare in this respect with the Atlantic coast? About how long is San Francisco Bay? How wide? About how many square miles does it include? About what proportion has a depth of four fathoms or more? How wide is the opening to the Pacific? How long? How deep? What is it called?

Where is Mare Island? For what is it noted? What rivers enter San Francisco Bay?

Harbor Chart. — Where is San Francisco located? What city on the opposite side of the bay? What is the depth of water along the San Francisco water front? Along the Oakland water front? How long are the piers on the Oakland front? On the San Francisco front? Why is the water front of San Francisco on the northeast instead of the north or the southeast side of the city?

Compare the harbor in all respects with that of New York, Boston, and New Orleans. What railroads have

their terminus at San Francisco Bay? What region is immediately tributary to this harbor?

San Francisco Bay has been termed a rias harbor. A rias coast is one somewhat resembling a fiord coast; but not caused by glaciation.

170. A CORAL REEF HARBOR

*PART I. *Key West, Florida. Coast Chart No.* 469, *Key West Harbor.* — How far, and in what direction, is Key West from Florida? From Havana? From New Orleans? Why is a harbor needed in this region? What are the keys and reefs made of? Do you think the keys make high land? What is the average depth of Man-of-War Harbor? About how many square miles does it contain? By how many channels is the harbor approached? What advantages has this harbor? What disadvantages? Do you think this harbor is used because of its excellence or because of its position? What is the mean rise and fall of tides here (see Tides)? How does this compare with New York? Why?

PART II. *Harbor of Apra, Island of Guam. Chart No.* 1850, *Hydrographic Office.* — What is the latitude and longitude of Guam Island (see chart)? How far, and in what direction, from San Francisco (measure on a globe)? From Hong Kong? From Manila? From Honolulu? What is the average depth of the harbor?

About what is its area? How near can ships approach Sumay? Apra? How many entrances to the harbor? Is the small number of entrances an advantage or a disadvantage? How deep is the entrance? Would it be likely to be as deep if there were more entrances? What beacons determine the paths of entering vessels? What is the average height of tide? How does this compare with New York? Boston? San Francisco? Is this feature favorable or not? What cables lead from this port? What strategic value has the island of Guam? What value has the harbor as a naval station? What points of advantage has the harbor? What disadvantages?

*171. A FIORD HARBOR

Bath Harbor, Maine. Bath Quadrangle, Maine. Chart No. 314, *Kennebec and Sheepscot Rivers.* — In what part of the state is Bath? What is the nature of the surrounding country? What river in the vicinity? How long is this river (see a map of the state)? What is the general shape of the coast? What is the average width of the fiord on which Bath is situated? The average depth of water? Is there much mud and silt at the bottom of Kennebec River? What reasons would account for this? Is the seaward passage straight or crooked? How does it compare in this respect with Boston? With New York? Are the tides high or low? What points of advantage has

Bath Harbor? What disadvantages? Why is Bath not a commercial center?

172. AN ATOLL HARBOR

Funafuto Atoll. Chart No. 1802, *Hydrographic Office.* — What is the latitude and longitude of this atoll? How far, and in what direction, from San Francisco? (Measure on a globe.) From Hong Kong? From Manila? What part of the atoll is used for anchorage? How deep is the water? How high is the land to the eastward of the anchorage? What advantages has this anchorage over other parts of the atoll? How is the anchorage entered? What general advantages of this harbor? What disadvantages?

173. A HOOK HARBOR

Provincetown Harbor. Provincetown Quadrangle, Massachusetts. Chart No. 110, *Cape Cod Bay.* — On how many sides is this harbor protected by land? Is it protected in directions from which high waves are likely to come? What is the average depth of the harbor? Is the deepest part near the "hook"? Why? Can ships get near the shore? Why? What valuable qualities has the harbor?

174. A SPIT HARBOR

Plymouth Harbor. Plymouth Quadrangle, Massachusetts. Chart No. 110, *Cape Cod Bay.* How long is

Long Beach? About how wide is Plymouth Harbor? How deep is the harbor? Would it be suitable for modern commerce? How many and what valuable qualities has this harbor?

175. A TIED ISLAND HARBOR

Marblehead Harbor. Boston Bay Quadrangle, Massachusetts. Chart of Salem Harbor, No. 244. — How deep is Marblehead Harbor? In what direction is it best protected from winds? From waves? Is it deep enough for modern commerce? What closes the harbor on the south? Why is it so shallow at the southern end?

CHAPTER XVII

SOILS

*176. SOILS ALONG AN AGGRADING RIVER

New Orleans Quadrangle, Louisiana. — Review Exercise 57. Where is the higher land of the area? What is its origin? What is its type of soil (see soil section, Figure 42)? What are the types of soil on either side? What is their origin? Which soil is most easily drained?

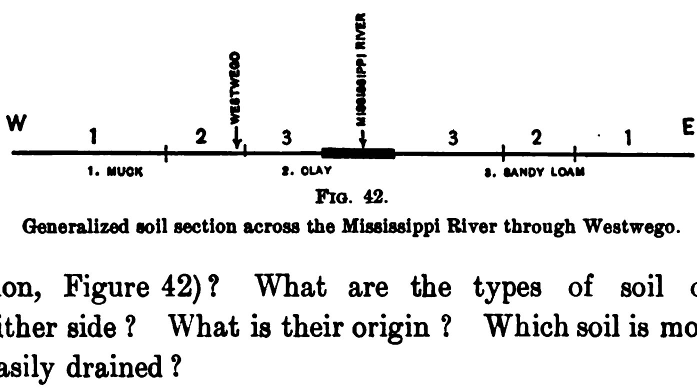


FIG. 42.

Generalized soil section across the Mississippi River through Westwego.

Sugar cane is largely raised in this region. It requires a well-drained soil. Where can it be best raised? Rice is also grown. The crop is flooded at times. What lands are suitable for this?

REFERENCE.— Soil Survey of the New Orleans Area, 1903.

*177. SOILS ON COALESCED ALLUVIAL FANS

Cucamonga Quadrangle, California. — Review Exercise 60. What is the origin of the alluvial fans? What distinction between an alluvial fan and a delta? Which usually is composed of the coarser materials? Why?

From the base of the mountains about to Cucamonga and Claremont, are gravels. From this gravel region a belt of sands and sandy loams extends nearly to Chino.

How would you explain this gradation in material? Which belt, do you think, offers the best soils? Which shows the densest population?

Before the wash from the mountain streams covered the bottom of the valley, the surface was rough. One of the old hills stands above the fans in the southwestern corner of the map. How high does it stand above the plain? It has a loam soil with considerable mica. From this, of what would you infer the underlying rock to be composed?

The San Gabriel Timber Land Reserve is carefully kept covered with timber on account of the effects of the timber on the streams. Explain this effect.

What are the principal agricultural products of southern California?

Reference. — Soil Survey of the San Bernardino Valley, California, 1904.

178. VALLEY SOILS DUE TO WASH FROM THE UPLANDS

Manti Quadrangle, Utah. — The Sevier River Valley, in the southwestern part of the quadrangle, is the area that has been mapped. How far, and in what direction, from Salt Lake City is this region? What mountains on the west? How deep is the valley?

How wide is the valley at the soil section shown in Figure 43? The rocks of the eastern upland are dark

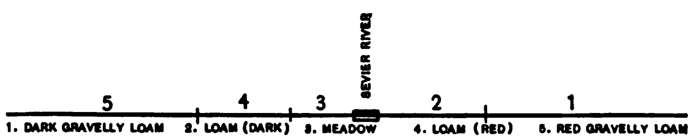


FIG. 43.

Soil section five miles south of Gunnison.

crystalline rocks. Those of the valley mountains are composed of red sandstone. The loams on the eastern side of the valley, are dark and those on the western side are red. Why? Why are the loams on the outer margin of the valley gravelly, while those nearer the center are not gravelly? The "meadow" soil is alluvial land. What is the origin of the loams on either side of the "meadow" soils? How were they transported?

REFERENCE. — Soil Survey of the Sevier Valley, Utah, 1900.

*179. SOILS ON RIVER TERRACES

Hartford Quadrangle, Connecticut.—Review Exercise 63. Where are the terraces? How were they formed? Of what materials are they composed? Locate the soil section shown in Figure 44. The meadows soil is a loam with considerable silt and humus. It is subject to overflow by the river. Why should it contain more silt and humus than the terrace soils? Both of these soils are

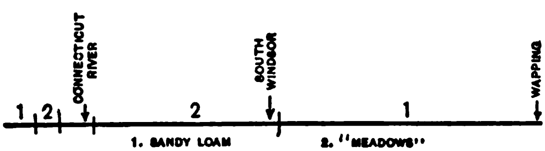


FIG. 44.

Generalized soil section from Wapping through South Windsor to the crest of the hill across the Connecticut River.

extensively used for tobacco growing. Why should they be fertile?

REFERENCE. — Soil Survey of the Connecticut Valley, 1903.

*180. SOILS ON LAKE SHORES AND BOTTOMS

Berea Quadrangle, Ohio. — Review Exercise 158. What is the origin of the ridges? These ridges have a loam soil with considerable gravel and sand. Between them are patches of clay and of a loam derived from till. Is clay laid down in quiet or active water? Why should not the clay be in the ridges? Why should

there be gravel and sand in the ridges and clay to the northward of the ridges? The till loam is found where either the surface was not covered by clay or the clay has been eroded.

Which of these soils have the best drainage? The gravel ridges are much utilized for orchards.

REFERENCE.—Soil Survey of the Cleveland, Ohio, Area, 1905.

181. SOILS IN A REGION OF RIDGES

Greenville Quadrangle, Tennessee–North Carolina.— What region have you studied that has the same features? How are the rocks arranged (see structure section, Figure 45)? What kind of rocks make the Holston valley? Bays Mountain and the parallel ridge to the northwest? The Nolichucky Valley? Bald Mountains?

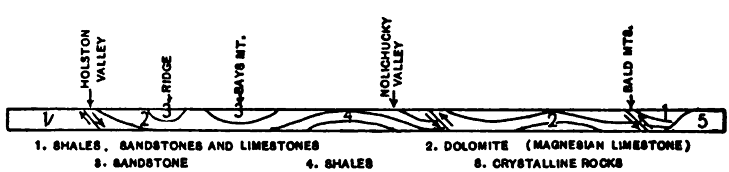


FIG. 45.
Generalized structure section in the Greenville Region.

The ridges have a stony loam which contains numerous sandy bowlders. Why? What kind of a drainage, good or poor, has it? The soil is subject to leaching. Why? Would such a soil have a high content of lime

and potash? Why? Much of it is left in forest. Would such a soil have much humus? Why?

The lowland belts have many clay loams and shale loams. The limestone often yields a clay soil. Why?

REFERENCES. — Greenville Folio, U.S.G.S.; Soil Survey of the Greenville Area, Tennessee, 1906.

182. ARREDONO QUADRANGLE, FLORIDA

The soil is sandy. The types differ in the amount of humus. One of the best types extends northeast-southwest through Gainesville and is about five miles wide. This belt is fairly well drained. How? Another type includes more organic matter (humus). These areas of soils with humus include the triangular area included between the two railroads north of Gainesville, the Hogtown Prairie, and the borders of Alachua Lake. What drainage features are largely responsible for difference in humus? Which area is most densely populated?

REFERENCE. — Soil Survey of the Gainesville Area, Florida, 1904.

183. SOILS ON GROUND MORAINE AND DRUMLINS

Palmyra Quadrangle, New York. — Of what are drumlins mainly composed? They are largely covered by a stony loam. What is a loam? Why stony? What about the drainage of drumlins? They contain many apple orchards. Why?

Between the drumlins is low meadow land. Is it as well drained as the land in the drumlins? Peppermint and onions are often grown on this soil.

REFERENCE. — Soil Survey of Lyons Area, New York, 1902.

*184. SOILS ON A MORAINE AND OUTWASH PLAIN

Islip Quadrangle, New York. — Review Exercise 118. What is the cause of the two ranges of hills, the plain between them, and the plain to the south? The hills are generally capped by a loamy soil often containing numerous bowlders. What is the origin of these bowlders? The plains are covered by sand and gravel loams and in places by pure sand. What is their origin?

Truck gardening is the principal agricultural activity of Long Island. Why? Which soils are most easily drained? Which are warmer? Which are best adapted to early vegetables? Why?

In many places the water table is too low for plant roots to reach it. What kind of soil would have this difficulty?

Draw diagram showing the profile. Name the principal topographic features (moraines, etc.), and indicate the principal soil types on these features.

REFERENCE. — Soil Survey of Long Island, New York, 1903.

CHAPTER XVIII

STUDIES OF TYPICAL AREAS

*185. THE RED RIVER VALLEY. A YOUTHFUL LAKE PLAIN

THE following grouped maps:[1] *Fargo, Casselton,* and *Tower* (*N.D.*).

Shade this area on a general map. What is its average altitude above sea level? What variations in altitude? Where is the most nearly level country?

A portion of this region was covered by the glacial Lake Agassiz. Most of it is underlain by till, but where the lake stood the till is covered by lake sediments. In the western part of the area, near Buffalo, is a marginal moraine which was not covered by the lake waters. Note all the evidences of a moraine. The shore line is east of this moraine. What is the slope of the shore line? From Watson to Walcott is the margin of a delta that was built into Lake Agassiz. Trace its margin. Are its slopes steeper or less steep than in the rest of the shore line? Why?

Account for the soil types shown in Figure 46. What river drains this plain? Is the drainage well organized? After a rain, farmers on the level portion often have to wait a week for the water to disappear.

[1] For suggestions as to mounting grouped maps, see Appendix.

What relation has this fact to the previous question? Why can the railroads be built so straight?

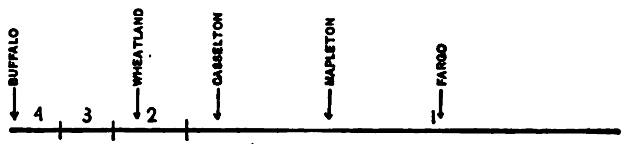


FIG. 46.

REFERENCES. — "The Glacial Lake Agassiz" by Warren Upham; Monograph 25, U.S.G.S.; Soil Survey of the Fargo Area, N.D., 1903.

BISMARCK, N.D.

	T.	P.	SNOW	R.H.
January . . .	7°	0.7 in.	5.4 in.	72.5
February . . .	9°	0.6 in.	4.9 in.	74.0
March	22°	1.0 in.	7.7 in.	72.5
April	43°	2.2 in.	2.5 in.	66.5
May	55°	2.6 in.	1.4 in.	64.5
June	64°	3.6 in.	0.0 in.	70.0
July	70°	2.6 in.	0.0 in.	62.5
August . . .	68°	2.1 in.	0.0 in.	58.5
September . .	57°	1.0 in.	0.0 in.	65.0
October . . .	44°	1.1 in.	0.8 in.	72.5
November . .	26°	0.6 in.	6.3 in.	75.5
December . .	15°	0.7 in.	4.8 in.	72.5
Year	40°	18.8 in.	34.6 in.	69.0

Average dates of last killing frost in spring, May 15.
Average dates of first killing frost in autumn, September 15.
Mean annual per cent of possible sunshine, 57.
General wind direction, N.W.

Bismarck is the type station for this part of the state. How far, and in what direction, is it from Fargo?

Plot the temperature curve. What is the monthly range (difference between the highest and lowest monthly temperatures)? When is the maximum? The minimum? Is the transition from winter to spring and from autumn to winter sudden or gradual? So far as temperature is concerned, is this climate continental or marine? Why? How long is the season that is free from frost?

Plot the precipitation curve. When is the maximum? The minimum? Is the transition between the maximum and minimum sudden or abrupt? This distribution of precipitation has been called the Missouri type. It is, in general, typical for the Great Plains. What percentage of the total precipitation falls in the spring? For how many months, on the average, is there snow on the ground? What percentage of the total precipitation is snow? (On the average ten inches of snow make one inch of water.) Is the snow fall heavy? Does it, on the average, reach one foot? What months are free from frost? What is the percentage of possible sunshine? Does this, on the whole, indicate sunny or cloudy weather? What general wind direction?

The Red River Valley is one of the great spring wheat regions of the country. Wheat does best with a

cool, moist growing season and a dry, sunny, hot ripening and harvesting season. What conditions of temperature, rain, snow fall, and frost do not favor winter wheat growing? What conditions of temperature, precipitation, relative humidity, and sunshine favor spring wheat? Extensive wheat growing also demands a surface on which machinery can be used. How does this plain meet this requirement?

*186. MATURE AND OLD PLAINS

Caldwell, Cheney, Kingman, and Anthony, Kan., Grouped Sheets. — Shade on a general map the area included in this map. In what part of the state is this area? What is the average altitude of this region? What is the principal river? Into what does it flow? How does this region compare in dissection with the Fargo, N.D., region? How, in stream arrangement and organization? The rocks underlying the region are rather weak. How would the hills and valleys differ from the present ones if the rocks were strong? What kind of a sky line, level or broken, do you think you would see from the hill tops? Where is there an area of sand dunes? Would you infer from the number of towns that the region is productive? What railroads cross the plains here? Why do they run so straight?

Where are the plains in this region in a mature stage of dissection? Where, in an old stage?

Hot wind at Dodge City, Kan. (*Average temperatures and relative humidities are given.*)

	T.	R.H.	Wind Velocity	Wind Direction	State of Sky
September 11, 1882	72.5°	31.0	17	W.	Clear
September 12, 1882	82.5°	29.5	22	S.W.	Clear
September 13, 1882	78.5°	31.5	22	S.	Clear
September 14, 1882	76.5°	38.5	30	S.W.	Clear

How far, and in what direction, is Dodge City from the areas shown in the mounted map?

Occasionally hot winds blow over the high plains. The data for a typical hot wind are given above. These are often very destructive to crops because of the withering effect. What two factors contribute most to this effect? Is the temperature excessive? Is the wind velocity high or low? The average relative humidity? What effect have these factors on evaporation? What effect does the state of sky have? What prevailing wind direction? What effect have these directions upon temperatures? Give at least two reasons.

*187. A SECTION ACROSS NEW YORK. THE ONTARIO PLAIN AND THE ALLEGHANY PLATEAU

The following grouped maps: *Sodus Bay, Oswego, Fulton, Mexico, Syracuse, Baldwinsville, Weedsport, Clyde.*

Geneva, Auburn, Skaneateles, Tully, Cortland, Moravia, Genoa, Ovid.

Watkins, Ithaca, Dryden, Hartford, Apalachin, Owego, Waverly, Elmira.

Shade the area on a general map. In what part of the state is the area located? What two physiographic divisions in this area? What is the average width of the lowland (Ontario Plain)? Its average height? Slope? What is the average height of the upland (Alleghany Plateau)? Trace the junction of the plateau and plain. Is the boundary distinct? Is it in this locality an escarpment? How does it compare in this respect with the Niagara region (see Exercise 86)?

What is the altitude of Lake Ontario? How would you describe its shore line? Are the numerous bays open? In general, is it a cliff shore or a built shore? What are the numerous hills (see Exercise 124)? What is their average height? How do they differ from those in Wisconsin? How do those north differ from those south? Trace the outlet of Seneca Lake. What different names has it? Do you think it is a normal stream? Why? Trace Oneida River. What lake does it drain? To what agency is its peculiar course due? What evidences of glaciation in this region? Trace the northern edge of the plateau. Where is it distinct? Where, indistinct? What is the height of the plateau in the lake region? What "finger" lakes traverse the plateau? What is the length and average width of Lakes Seneca, Cayuga, Owasco, and Skaneateles? What

similar valleys are not occupied by lakes? Which end of the lake valleys is partially filled? How were they filled? Examine the valleys for hanging deltas (see Exercise 127). How were these deltas formed? Note the valley leading north from Cortland. Where is the divide in this valley? A marginal moraine crosses this valley. Locate it. What morainal features has it? Why is a divide so located not a result of normal erosion? A moraine crosses the Seneca Valley at Montour Falls. Find one south of Ithaca. Can you trace the moraine on the upland? Why is it more distinct in the deep valleys? Find the same feature in Pony Hollow, southwest of Ithaca.

The "finger" lake valleys were scoured and deepened by ice erosion. How do they differ from the work of normal erosion in inter-valley divides, depth, dissection of valley sides, behavior of tributaries, and organization of drainage?

Near the close of the glacial period, marginal glacial lakes were formed in these valleys. Why? Which way would these lakes outflow? Find the outflow channel of the lake occupying the Seneca Valley. Describe it. Explain the behavior of Catharine Creek (north of Horseheads). Account for the abandoned valley of the Chemung in the Elmira area (see also Exercise 66).

Where in this area are the towns and villages most frequent? Where are railroads most numerous? How

would you account for this? Trace the Erie Canal. What physiographic feature does it follow? From a census report of 1890 or 1900, determine the population per square mile and the farm values for the following, counties included, for the most part, in this area: Chemung, Tioga, Tompkins, Seneca, and Cayuga. Locate these counties and account for their population and farm values.

The Ontario plain in its northern portion has a climatic modification due to Lake Ontario. The same is true along the eastern and southern shore of Lake Erie, where there is the important "grape belt."

AVERAGE MONTHLY TEMPERATURE AT OSWEGO AND ITHACA

	OSWEGO	ITHACA		OSWEGO	ITHACA
Jan.	24°	24°	Aug.	68°	68°
Feb.	24°	25°	Sept.	62°	61°
March	31°	32°	Oct.	51°	50°
April	43°	45°	Nov.	39°	38°
May	54°	57°	Dec.	28°	29°
June	64°	66°	Year	46°	47°
July	70°	70°			

First killing frost in autumn: Oswego, October 13; Ithaca, September 24.

Last killing frost in spring: Oswego, April 25; Ithaca, May 22.

Locate Oswego and Ithaca. What are their altitudes? Their difference in altitude? Plot the temperature curves for Oswego and Ithaca (use about three

small squares for each degree). What is the average annual temperature for each place? At which place is the change from winter to spring and from autumn to winter most abrupt? Why? So far as altitude is concerned, which place would have the coolest spring? What is the length of the season free from frost at the two places? Which has the longest season free from frost? Fully explain your answer. What relation to these facts has the location of the fruit and grape belts near the lake?

*188. THE COASTAL PLAIN, PIEDMONT PLATEAU, AND HIGHLANDS IN NEW JERSEY

The following grouped maps: *Trenton, N.J.–Pa., Navesink, N.J.–N.Y., Passaic, N.J.–N.Y., and Raritan, N.J.* — Shade on a general map the area of this map. What part of the state is included?

Looking from the northwest to the southeast corner of the map, what highlands and what lowlands do you find extending across the region? Draw a sketch map locating New York, Jersey City, Paterson, Morristown, New Brunswick, Trenton, Princeton, and Long Branch. Locate also the principal rivers and ridges.

What kind of rock underlies the different divisions of New Jersey (see Figure 47)? What two kinds of rock underly the eastern lowlands (Coastal Plain)? What is the arrangement of these rocks? What

divisions of the Coastal Plain (see Exercise 104)? Which rocks make inner lowlands? What covers the outer slope? Trace the cuesta. Is it continuous? Is it smooth? What is its average height?

Generally speaking, the Highlands in New Jersey include the region between the Coastal Plain and the

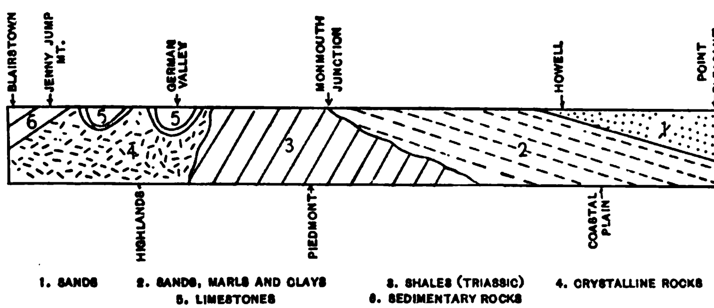


FIG. 47.

Generalized section from Blairstown (Raritan Quadrangle, N.W.) to Point Pleasant (Navesink Quadrangle, S.E.).

ridges in the vicinity of Jenny Jump Mountain. It is divided into two parts: the Highlands proper, which includes the area of crystalline rocks, and the Piedmont Plateau, which is underlaid by shales and sandstones (Triassic) (see Figure 47). What is the average height of the Highlands? Of the Piedmont Plateau? Is there a sharp division between the Piedmont Plateau and the Coastal Plain? Is the slope between them gentle or abrupt? On the average, what is the slope per mile? This junction is called the Fall Line.

What feature in the Delaware River marks this junction (above Trenton)? Why, then, is this line called the Fall Line? What is the origin of the valleys in the Highlands (see Figure 47)? Leaving out the valleys, are the altitudes on the Highlands and Piedmont about the same?

What are the heights of the First and Second Watchung Mountains and of Long Hill? What is their origin (see Figure 48)? The ridge on which Jersey City is located has the same origin.

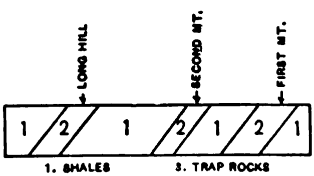


FIG. 48.

Generalized section from Plainfield to Pleasant Plains (Passaic Quadrangle).

Northwest of Jenny Jump Mountain is the Ridge Belt. Judging from the evidences shown on the map, what part of this region is glaciated? What evidences? What rivers flow along the inner lowland? What rivers cross it? Indicate on your sketch map the Coastal Plain, Piedmont Plateau, the Highlands, and the Ridge Belt.

Trace the Delaware and Raritan Canal. It was one of the first built in this country. What physiographic factors favored its construction? What commercial factors? One of the early railroads was also built in the same region. Why? What important railroads in this region? Where are most of the towns and cities?

Soils of the Trenton Area.—What soils are found in

different divisions of the area (Figure 49)? Which soils are situated for good drainage? Greensand often

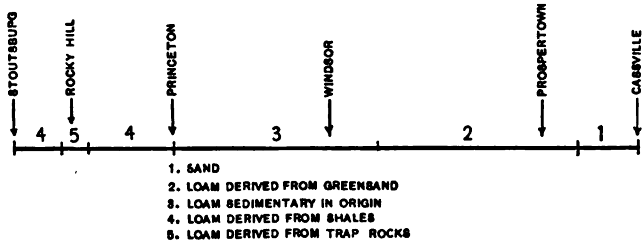


FIG. 49.

Generalized soil section from Stoutsburg (Trenton Quadrangle, N.W.) to Cassville (Navesink Quadrangle, S.W.).

yields a fertile marly soil. Much of the agriculture on the sand is devoted to fruits and truck crops. Why?

	Seacoast	Highlands		Seacoast	Highlands
	T.	T.		T.	T.
January . .	30.0°	26.5°	August .	72.8°	70.2°
February .	30.6°	26.7°	September .	67.4°	63.6°
March . .	38.3°	35.5°	October . .	56.5°	51.8°
April . . .	48.4°	48.0°	November .	45.4°	40.8°
May . . .	59.1°	59.0°	December .	35.9°	31.0°
June . . .	68.6°	67.9°	Year . . .	52.8°	49.3°
July . . .	73.3°	71.9°			

First killing frost in autumn: Highlands, October 4; Seacoast, October 21.

Last killing frost in spring: Highlands, May 10; Seacoast, April 19.

Average precipitation: Highlands, 49.1 inches; Seacoast, 46.6 inches.

(Soil warmth and drainage are important factors in these crops.)

REFERENCES. — Soil Surveys of the Trenton, N.J., and of the Salem, N.J., Areas.

Plot the temperatures for the Highlands and the seacoast. (Use about three small squares per degree.) What differences between the Highlands and the seacoast? How do the graphs compare with those of Oswego and Ithaca? What average differences in the frost season? Which locality is best adapted for melons and truck crops? Which, for dairying and cereals? How does the frost season compare with that of Fargo, N.D.? How does the total precipitation compare with that of Fargo? What good markets are accessible to the farmers of New Jersey?

Supplementary: Trace Washington's campaigns in this area. What reasons are apparent for his selection of Morristown as his base?

189. THE COASTAL PLAIN, PIEDMONT PLATEAU, BLUE RIDGE, GREAT VALLEY, RIDGE BELT, AND ALLEGHANY PLATEAU IN MARYLAND, VIRGINIA, AND WEST VIRGINIA

The following grouped maps: (*Md.*) *Green Run, Ocean City, Pittsville, Snow Hill, Princess Anne, Salisbury, Nanticoke, Deal Island.*

Crapo, Oxford, Bloodsworth Island, Sharps Island, Drum Point, Point Lookout, Prince Frederick, Leonardtown, Piney Point, Montross, Wicomico, Brandywine.

(*Va.*) *Fredericksburg, Mount Vernon, Harpers Ferry,*

Warrenton, Spottsylvania, Gordonsville, Luray, Winchester.

(*W. Va.*) *Romney,* (*Va.*) *Woodstock, Harrisonburg, Staunton,* (*W. Va.*) *Franklin, Piedmont, St. George, Beverly, Monterey, Buckhannon, Huntersville, Nicholas, Sutton.*

What is the length in miles of this strip (note that there are two scales)? Locate it on a general map. Shade the area mapped. Make a profile along the parallel of 38°. (Use only the 100-foot contours, and a scale of 10 miles to the inch. Let different members of the class draw a profile for one quadrangle. The different profiles can then be joined. Allow one small square to represent 100 feet in altitude.) Where do you think the rocks are folded? Where are they horizontal or massive? Locate Washington, Fredericksburg.

The Coastal Plain. The Eastern Maryland Maps. — Describe the coast line. Where have you seen a similar coast? How wide is the off-shore bar? With what is it largely covered? How wide is the lagoon? How would you describe the shore line of the mainland? How would you account for it?

What is the width of the region between the Atlantic and Chesapeake Bay? What is its average height? What habit have most of the rivers? How would you account for this? What peculiarity of the shore line along Chesapeake Bay? How wide is Chesapeake Bay

here? What is the general elevation of the Coastal Plain west of the Chesapeake Bay? Do you think this part of the plain is older or younger than the plain east of Chesapeake Bay? Which part is the more dissected? How would their height and relative ages affect their dissection? To what forms is the term *neck* applied? What is the width of the Wicomico River? Of Chaptico Bay? How would you explain these widths?

The Piedmont Plateau. — What change in altitude in the vicinity of Fredericksburg and Washington? Here is the meeting of the Piedmont Plateau and the Coastal Plain. Trace this line across the map (the Fall Line). What is its average slope? What feature on the Potomac near the Fall Line? What similar feature on the Delaware (see Exercise 188)? What, on the James in Richmond (see Richmond Quadrangle)? Compare the rivers and their valleys on either side of the Fall Line. The Piedmont Plateau extends westward to the Blue Ridge. How would you describe the Piedmont Plateau, as level, rolling, or mountainous? How does it compare in this respect with the Coastal Plain? The plateau has been peneplained and subsequently elevated. What evidence of this is found in the valleys, in the altitudes, and in such monadnocks as Mount Pony and Thoroughfare Mountain?

The Blue Ridge, Great Valley, and Ridge Belt. — How wide is the Blue Ridge on the average? What is

its average height? Where is it narrowest? Which margin, the east or the west, is steeper? Which margin is more distinct? What direction is its trend? West of the Blue Ridge is the Great Valley and the belt of Appalachian Ridges. How wide is the Great Valley? How deep below the Blue Ridge is it? What river drains it? Does it widen or narrow to the southward?

What is the average width of the Ridge Belt? How many ridges in its northern part? Southern part? What is the trend of the ridges? What is their average height above the valleys? Above sea level?

What is the drainage pattern in this belt? Where are most of the roads and railroads? Where do the roads cross the ridges? Why are the roads so crooked? Are the openings in the ridges wind gaps or water gaps, or both? What is the origin of the wind gaps (see Exercise 98)? What is the probable origin of the water gaps (see Exercise 76)?

Is the transition from this belt to the plateau westward gradual or abrupt? The Alleghany Front is usually taken as the western boundary of the Ridge Belt. What is its structure (Figure 50)? Why does this structure cause an escarpment? How are the rocks arranged west of the Alleghany Front? What causes Backbone Mountain and Hoop Pole Ridge? Where have you seen a similar example (Exercise 92)?

The Alleghany Plateau. — What is the average elevation above sea level? How does its dissection compare with that of the Piedmont? Of the Coastal Plain? What, would you infer, is the arrangement of its rocks, horizontal or folded? What is the general stream pattern? Are the ridges and valleys parallel, as in the

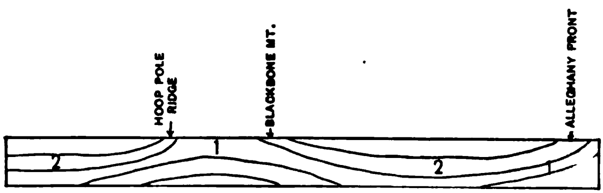


FIG. 50.

Section through Hoop Pole Ridge across the Alleghany Front.

Ridge Belt? Why? In what stage of dissection is the surface? Compare the stream patterns and the topography in the Alleghany Plateau, the Ridge Belt, and Coastal Plain. Illustrate with a contour sketch of sixteen square miles a type area in each division.

Where are the roads found in each division? Explain the peculiarity of road location on the Coastal Plain. Where is most of the population? What reasons?

Supplementary: How is the Shenandoah Valley separated from the Piedmont Plateau? On a general map, trace the Shenandoah River. Work out the influence of this valley on various campaigns of the Civil War. See "Geographic Influences in American History,"

by A. P. Brigham, Chapter 7; "American History and its Geographic Conditions," by Ellen C. Semple, Chapter 14; and *Journal of School Geography*, June, 1901.

*190. THE PIEDMONT PLATEAU, BLUE RIDGE, APPALACHIAN VALLEY, CUMBERLAND PLATEAU, AND NASHVILLE BASIN

The following grouped maps: (*N.C.*) *Yadkinville, Statesville, Hickory, Wilkesboro, Cranberry, Morgantown* (*note that some of these maps have different contour intervals*).

Roan Mountain, Mount Mitchell, Saluda, Pisgah, Ashville, (*Tenn.*) *Greenville, Morristown, Mount Guyot,* (*N.C.*) *Cowee, Nantahala,* (*Tenn.*) *Knoxville, Maynardsville.*

Briceville, Loudon, Murphy, Cleveland, Kingston, Wartburg, Standingstone, Pikeville, Chattanooga, Sewanee, McMinnville.

What is the latitude of these maps? The longitude? How do they compare in latitude and longitude with the maps in Exercise 189? Locate these maps on a general map, and shade their location on a blank map.

The Blue Ridge.—Trace the eastern border of the Blue Ridge. How does it compare in smoothness with the same feature in Virginia? In distinctness? In height? Are each of the indentations in the Blue Ridge occupied by a stream? To what are the indentations

due? Trace the Yadkin River; the New River; the Catawba River; the French Broad River; the Nolichucky River. Into what do they flow? Is the Blue Ridge a divide? Is it in Virginia? Which way in Virginia do the streams on either side of the Blue Ridge ultimately flow? In what way do they in this region? On which side of the Blue Ridge is the divide in North Carolina and in Virginia? What outliers from the Blue Ridge?

Trace the valley of the French Broad River. Where is it wide? Where, narrow? About how many square miles in the Asheville Valley? Find similar and smaller intermontane valleys.

Trace the westward-flowing rivers of the Blue Ridge. Which are steeper, their upper or lower courses? How do the valleys in their upper and lower courses compare? In like manner, trace the eastward-flowing rivers. How would you describe the western border of the Blue Ridge? The Unaka Mountains are an offshoot of the Blue Ridge. What names do they bear in this region? How does the western border compare with the same feature in Virginia?

How wide is the Blue Ridge Belt? What is the average height? Describe the surface. How does its width here compare with its width in Virginia? In New Jersey? (The Highlands in New Jersey are the counterpart of the Blue Ridge.)

Draw a sketch map of the Blue Ridge Belt, showing the principal rivers, mountains, towns, and railroads.

The Great Valley. — How wide, on the average, is the Great Valley? Where is it least interrupted by ridges? What river drains it?

The Ridge Belt. — How wide is the Ridge Belt? What is the average height of the ridges above the

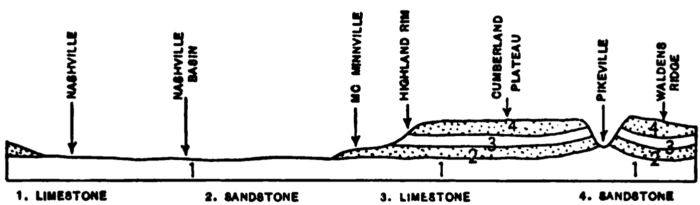


FIG. 51.

Generalized section from the Great Valley, through the Nashville Basin.

valley? Above sea level? What ridges are nearly or quite continuous through the area? What ridges have even crests? Which consist mainly of a line of hills? Which of these two classes of ridges, do you think, is sandstone or strong rock? Which is limestone? Compare the Ridge Belt with that in Virginia. What rivers unite to form the Tennessee? What city near their confluence? What escarpment bounds the Ridge Belt on the west? What is its structure (Figure 51)? Compare it in structure and height with the Alleghany Front. How is the course of the Tennessee River in the valley and in the plateau somewhat peculiar? What geographic factors in the location of Chattanooga? Why

was it a place of high strategic importance in the Civil War? What is the origin of the Sequatchie Valley (Exercise 91)?

The Cumberland Plateau. — What is the average height of the Cumberland Plateau? With what plateau does it correspond in West Virginia? In New York? How do the valleys of the plateau and the Great Appalachian Valley compare in width, cross section, and depth? How is the valley cross section in the plateau to be explained by the plateau structure (see Exercise 82)? (The plateau surface is underlain by a stratum of sandstone beneath which is limestone.) How much below the general average height of the plateau is the Great Valley? Compare the eastern and western margins of the eastern part of the Cumberland Plateau.

The Nashville Basin. — West of the Cumberland Plateau is the Nashville Basin. The escarpment overlooking this basin is called the Highland Rim. Trace this escarpment from McMinnville to Standingstone. How does it compare with the Niagara escarpment? The Alleghany Front? The Cumberland escarpment? What causes its uneven front? What keeps the escarpment steep (see Exercise 86 and Figure 51)? The Nashville Basin is underlain with limestone. What kind of a soil has the basin? The plateau? Which, do you think, is the more fertile?

If you have the Nashville Quadrangle, note the western boundary of the Nashville Basin. Where is the Highland Rim? How high is it? Compare its surface with that of the Nashville Basin.

The Cumberland Gap. Cumberland Gap Quadrangle. — Locate this quadrangle with reference to your grouped maps. Locate Cumberland Gap. What three states have a junction near the gap? Through what mountain does the gap give a passage? How far below the crest of the mountain is the floor of the gap? What river leads to the gap from the east? What, from the west? From a general map of the region, trace these rivers. To what is Powell River tributary? Cumberland River? Make a sketch map showing the relation of the rivers to the gap. Thousands of pioneers passed westward through this gap. Why?

What streams head near the gap? What does this fact suggest as to its origin? Where have you seen similar examples (Exercise 88)?

Read the chapters pertaining to the route through Cumberland Gap in Hurlbut's "Cumberland Road."

Plot the temperature curves for Nashville, Asheville, and Atlanta. Plot the precipitation curves for Nashville and Atlanta. How do they compare with that of Fargo, N.D.? The curve for Nashville is typical in general for the North and South Atlantic states, the

Ohio Valley, and the Appalachian regions. How would you account for differences in temperature between Nashville and Asheville (note the elevations)?

	Asheville, N.C.	Nashville, Tenn.		Atlanta, Ga.	
	T.	T.	P.	T.	P.
Jan.	38°	38°	4.8 in.	42°	5.3 in.
Feb.	40°	41°	4.8 in.	46°	5.2 in.
March	46°	49°	5.3 in.	52°	5.9 in.
April	54°	59°	4.6 in.	61°	3.7 in.
May	63°	68°	3.5 in.	70°	3.3 in.
June	69°	76°	4.2 in.	76°	4.0 in.
July	72°	80°	4.4 in.	78°	4.8 in.
Aug.	71°	78°	3.4 in.	77°	4.5 in.
Sept.	65°	71°	3.7 in.	72°	3.0 in.
Oct.	54°	60°	2.3 in.	62°	2.3 in.
Nov.	45°	48°	3.8 in.	52°	3.5 in.
Dec.	39°	41°	3.8 in.	44°	4.4 in.
Year	55°	59°	48.6 in.	61°	49.9 in.

First killing frost in autumn: Asheville, October 20; Nashville, October 24; Atlanta, November 7.

Last killing frost in spring: Asheville, April 22; Nashville, April 2; Atlanta, March 24.

Some cotton has been grown in the Nashville Basin. Atlanta is the center of an important cotton-growing region. Cotton needs during the growing season four to five months of high temperature and abundant rainfall. During the ripening season, high temperature and dryer weather are needed while wet weather during

the picking season is destructive. Killing frosts should not come later than April 1 or earlier than November 1. Compare in all these respects the tables for Nashville and Atlanta. Why cannot cotton be grown in North Dakota? Can wheat be grown in Tennessee?

From a census report, find the population, farm values, average size of farms, and farm products of the following counties: Yadkin, N.C., Wilkes, N.C., Watauga, N.C., Carter, Tenn., Greene, Tenn., Hamblen, Tenn., Grainger, Tenn., Union, Tenn., Anderson, Tenn., Morgan, Tenn., Davidson, Tenn. Which are wholly in the Blue Ridge Belt? Which, in the Appalachian Valley? Which, in the valley of the Tennessee? Which, in the Cumberland Plateau? (Different members of the class may be assigned different counties.)

Along the parallel of 35° 30′, make a profile across the region of these maps. Use only the 100-foot contours and a scale of three miles to an inch. It would be well for each student to draw the profile for one quadrangle. These profiles can be pasted together.

References. — "The Southern Appalachians" in the "Physiography of the United States"; Soil Survey of Davidson County, Tenn., 1903.

Supplementary: Study the campaigns of the Civil War in the vicinity of Chattanooga. You will find a

close relation between the physiography of the region and the movements of the armies.[1]

191. A PORTION OF THE RIDGE BELT AND THE GREAT VALLEY IN PENNSYLVANIA

The following grouped maps: (*Pa.*) *Sunbury, Shamokin, Catawissa, Pine Grove, Lykens, Millersburg, Millerstown, New Bloomfield, Harrisburg, Hummelstown, Lebanon.*

*PART I. — Shade this area on a general map. In what part of Pennsylvania is it located? How far, and in what direction, from Philadelphia? What physiographic areas shown here? Locate the Great Valley. The Ridge Belt. What boundary of the Great Valley southeast of Lebanon? Review Exercises 92 and 93. Trace Blue Mountain, Second Mountain, Third Mountain. How does Third Mountain change as you trace it eastward? Trace Peters Mountain. What different names does it bear? What is its length?

From the structure section, Figure 52, determine the anticlines and synclines and the topography resulting from them. Note the Shamokin and Wiconisco coal basins. Are these basins in anticlines or synclines? The coal measures once covered the entire region. Why do

[1] See Chapter 14 in "American History and its Geographic Conditions"; *Journal of Geography*, February, 1905, or *Popular Science Monthly*, June, 1904; *Grant's Memoirs*, Vol. II; Chapter 7 in "Geographic Influences in American History."

they not at present? Where are towns most numerous? Why? Find longitudinal and transverse valleys. Find water gaps and wind gaps.

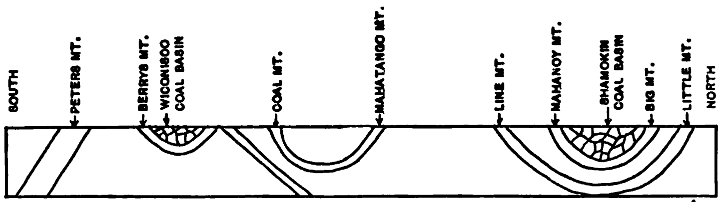


FIG. 52.

Generalized section from Peters Mt. through Little Mt. (Lykens and Shamokin quadrangles).

PART II. — Note the principal anticlines and synclines, and determine whether their axes are horizontal or pitching; and if pitching, in what directions do their axes pitch? Trace the peneplain described in Exercise 100. In which direction does it slope? In what stage of erosion would you class this region? Are the streams mostly adjusted? Find examples of adjusting streams (see Exercise 97). Note the Conodoguinet and Swatara Creeks. Would you expect them to meander with their present volume and grade? Why? How can their meandering be explained (see Exercises 75 and 76)? Does the Susquehanna River take an easy course? What is the probable explanation (see Exercise 76)? Find other examples of the same class.

192. THE COASTAL PLAIN IN FLORIDA

The following grouped sheets of Florida: *Williston, Citra, Dunnellon, Ocala, Tsala Apopka, Panasoffkee.* Review Exercises 138 and 182.

In what part of the state is this region? On a general map, shade the region of the maps. What direction is this region from St. Augustine? On a general map, trace the Withlacoochee River. What part of its course is shown in this map? What is the principal town? What is the average altitude above sea level? What is the highest surface? The lowest surface? Would you describe the surface as level or rolling? How does it compare with the outer part of the Maryland Coastal Plain? The inner (western) part? With a lake plain (Fargo, N.D.)?

Would you describe the drainage as good or poor? Organized, unorganized, or disorganized? Do you think the lakes along the streams are deep? Do you think they have the same origin as those in the Bayou Sara region (Exercise 62)?

In what respects does the topography west of Ocala resemble morainic topography? How does it differ? What is the origin of many of the streams, especially the Wekiwa Creek and Dead River (southwestern part)? Into what do many of the small creeks empty (*e.g.* Brooks Branch, northwest of Ocala)? Would you

describe the dissection of the region as youthful, mature, or old? What mines north of Ocala? For the soils of this region, review Exercise 182.

TAMPA, FLA. (ELEVATION 17 FEET)

	T.	P.		T.	P.
January . .	59°	2.8 in.	August . .	82°	8.4 in.
February .	62°	3.5 in.	September .	80°	8.2 in.
March . .	67°	2.9 in.	October .	74°	2.8 in.
April . .	70°	2.1 in.	November .	67°	1.7 in.
May . . .	76°	2.4 in.	December .	61°	1.8 in.
June . . .	80°	8.5 in.	Year. . .	72°	53.1 in.
July . . .	81°	8.0 in.			

First killing frost in autumn, January 9.
Last killing frost in spring, February 8.

How far, and in what direction, is Tampa from Ocala? What is their difference in altitude? Plot the temperatures for Tampa. How does your graph compare with that for Bismarck, N.D.? Nashville, Tenn.? Which region has the greatest monthly temperature range? The most abrupt changes between seasons? Plot the precipitations for Tampa. When is the maximum? The minimum? How does the graph compare with that for Nashville? For Bismarck? If this *type* of precipitation occurred in Dakota, would it be more or less suitable than the present type? Why?

What is the length of the frost season at Tampa? How does this compare with Nashville and Bismarck?

Florida is noted for its oranges and truck crops. What climatic features favor these crops?

*193. THE LOWER MISSISSIPPI VALLEY

(Review Exercise 176)

NEW ORLEANS

	T.	P.		T.	P.
January	54°	4.6 in.	August	82°	5.7 in.
February	57°	4.7 in.	September	79°	4.7 in.
March	63°	5.2 in.	October	70°	3.0 in.
April	69°	5.1 in.	November	61°	3.8 in.
May	75°	4.0 in.	December	55°	4.3 in.
June	81°	6.2 in.	Year	69°	57.6 in.
July	83°	6.3 in.			

First killing frost in autumn, December 15.
Last killing frost in spring, January 24.
Mean annual percentage of possible sunshine, 53.
Mean annual relative humidity, 77.

Plot the temperature and precipitation for New Orleans. What curves that you have made do they resemble? What is the length of the frost season? Can corn be grown here? Wheat? Sugar cane requires high temperature, ample rain, strong sunlight, and fertile soil. What climatic factors in Louisiana are favorable to sugar cane, and why?

*194. SOUTHERN NEW ENGLAND. CONNECTICUT

The following grouped maps: (*Conn.*) *Putnam, Moosup, Stonington, New London, Norwich, Woodstock, Tolland, Gilead, Saybrook, Guilford, Middletown, Hartford, Granby, Meriden, New Haven.*

Winsted, Waterbury, Derby, Bridgeport, Norwalk, Danbury, New Milford, Cornwall, (*Conn.–N.Y.*) *Middlebrook, Clove, Caramel* (*N.Y.*), *Stamford.*

Taking the state as a whole, what uplands? What lowlands? What percentage of the state is upland? What is the general altitude and slope from the northern part to the sea? Of the upland west of the Housatonic River? Between the Housatonic and the Connecticut? East of the Connecticut? Compare the surfaces of these three uplands. How wide are the respective highlands and lowlands? Locate New London, Hartford, New Haven, Middletown, Danbury, Bridgeport.

Trace the Connecticut River. Trace the lowland through which the Connecticut flows to Middletown. Does the Connecticut follow the lowland from Middletown to the sea? Where does the lowland reach the sea? The lowland is largely composed of sandstone, and the uplands of crystallines. Compare and explain the width, depth, and sides of the Connecticut Valley in the lowland and in the upland. Does the river

appear to take the easiest course? What similar example have you seen? In like manner, trace the lowland in which, for a distance, the Housatonic River flows, and also the river valley. How many linear ridges in the Connecticut Valley? What is their origin (see Figure 34)? Describe the slopes of these ridges. Are the slopes symmetrical? Aside from the valleys of the Connecticut and the Housatonic, describe the river valleys as to width, side slopes, and stage in erosion. In what stage of erosion would you say the surface of Connecticut is? Has the surface been glaciated? What are the evidences? Southeast of Westerly (southeast corner of the map) is a well-defined moraine. Locate and trace the moraine. What characteristics does it have? Has it an outwash plain? How does it differ from the adjacent country? How can you infer the ice-contact side? How would you describe the rivers in their lower courses? What other examples have you seen? How are they to be explained? To what type of sea coast does that of Connecticut correspond? Is it favorable for harbors? What physiographic areas include most of the cities? Compare the density of population, farm values, crops, and manufactures in these counties along the northern border of the state: Litchfield, Hartford, Tolland, and Windham. (See census reports of 1900.) Which are largely upland counties? Which lowland?

REFERENCES. — "Physical Geography of Southern New England," W. M. Davis, in "Physiography of the United States"; Soil Survey of the Connecticut Valley, 1903; Holyoke, Mass. Folio, U.S.G.S.

NEW HAVEN

	T.	P.	SNOW		T.	P.	SNOW
January	28°	4.0 in.	10.0 in.	August	70°	4.9 in.	0.0 in.
February	29°	4.0 in.	11.2 in.	September	64°	3.6 in.	0.0 in.
March	35°	4.5 in.	8.1 in.	October	53°	3.9 in.	*T
April	46°	3.5 in.	1.3 in.	November	41°	3.7 in.	3.3 in.
May	58°	3.7 in.	*T	December	32°	3.5 in.	6.4 in.
June	66°	2.9 in.	0.0 in.	Year	50°	47.2 in.	40.3 in.
July	72°	5.0 in.	0.0 in.				

* *"T" indicates an amount too small to measure.*

Average date for first killing frost in autumn, New Haven, October 17.
Average date for first killing frost in autumn, New England, September 23.
Average date for last killing frost in spring, New Haven, April 20.
Average date for last killing frost in spring, New England, May 12.
Mean annual relative humidity, New Haven, 75.

Plot the temperatures for New Haven. What is the maximum? Minimum? The monthly range? Is the change from summer to winter and from winter to summer gradual or abrupt? How does the graph compare in this respect with New Orleans and Tampa? How do the mean annual temperatures of these three places compare?

Plot the precipitation for New Haven. How does your graph compare with that of Bismarck and New

Orleans? Which graphs show the most variation in rainfall from month to month? The least? This distribution of rainfall, on the average, is typical for New England. What effect, favorable or unfavorable, has such a distribution of rainfall on the water power of New England rivers?

In what months does snow fall? How long is the snow season? What percentage of the total precipitation is snow? Does this percentage indicate much or little rain in the winter? How does New Haven compare in this respect with Bismarck, S.D.?

What is the length of the frost season for New England? For New Haven? How would you explain the difference? What differences in other climatic factors in New Haven and New England? What explanation can you suggest? How does the relative humidity compare with that of Bismarck? Would cotton grow in New England? Why? Would wheat? Why?

195. THE BLACK HILLS AND THE GREAT PLAINS

The following grouped maps: (*S.D.*) *Rapid*, *Hermosa*, *Oelrichs*, *Edgemont*, *Harney Peak*, *Deadwood*, (*Wyo.*) *Sundance*, *Newcastle*.

Shade this area on a general map. How far, and in what direction, is this region from Fargo? From Chicago? What states are included? How many principal areas of highlands and lowlands? How high, in

general, is the Plains area? The Black Hills area? Locate Rapid, Custer, Spearfish, Cheyenne River. Into what does this river flow? (See general map.)

Trace the elevation, beginning at Sturgis, near Rapid, through Hot Springs, Newcastle, and Sundance. Where is it most distinct? Where least distinct? Where is it widest? What is its average width? Average height? Are its slopes equal? What similar ridge have you studied (see Exercise 103)?

In like manner trace the valley west of Sturgis. Where is it widest? Where narrowest? What is its average width in the eastern part of the region? The southern part? The western part? What is its average depth below the outer ridge? Is this valley occupied by a river?

The inner area consists of a limestone plateau surrounding a deeply dissected plateau of crystalline rocks. Trace each area. About how large an area is included in the hilly portion of the map? How does the Black Hills surface compare with the Plains surface?

Make a profile east and west across the area about four miles north of Rapid. Correlate this profile with the structure section (Figure 53).

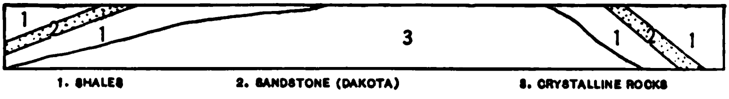


FIG. 53.

East-west Section across the Black Hills near Rapid, S.D. (After Darton.)

How do you account for the steep slopes of the outer ridge (hogbacks)? The inner circular valley? The high central region?

From the drainage, what can you infer as to the rainfall of the Black Hills as compared with the Plains? How much higher are the Black Hills than the Plains? What is the origin of the name, Black Hills (see an encyclopedia)? The Black Hills are the catchment region for much of the artesian water of the Plains. Explain this fact (see Figure 54). Why are the sandstones better water carriers than shales? Of what use in this connection are the overlying shales? The underlying shales?

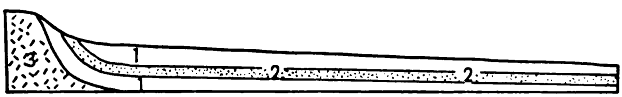


FIG. 54.

Generalized Section from the Black Hills across the Plains towards Yankton, S.D. The Dakota sandstone is the main water-bearing stratum. (After Darton.)

Problem. — Why is the "hogback," formed by the Dakota sandstone, wider on the west side of the Black Hills than on the east side (see structure section; also Exercise 99)?

How would you account for the number of towns in the Black Hills as contrasted with the Plains?

REFERENCES. — "The Southern Half of the Black Hills," N. H. Darton, 21st annual report, U.S.G.S., Part IV, pp. 489–598.

The following U. S. G. S. Folios: Edgemont, S.D., Oelrichs, S.D., Newcastle, Wyo. (Any one of these folios will give a brief description of the Black Hills region.)

BLACK HILLS AND PLAINS

	Spearfish, S.D. Altitude, 3647 Ft.		Oelrichs, S.D. Altitude, 3339 Ft.	
	T.	P.	T.	P.
January	25°	1.0 in.	23°	1.1 in.
February	21°	1.0 in.	20°	1.2 in.
March	30°	2.2 in.	31°	2.1 in.
April	46°	3.0 in.	46°	2.2 in.
May	55°	3.0 in.	57°	2.8 in.
June	64°	4.1 in.	66°	3.1 in.
July	71°	2.0 in.	73°	2.0 in.
August	70°	1.6 in.	72°	1.0 in.
September	60°	1.1 in.	60°	1.0 in.
October	49°	1.3 in.	48°	1.2 in.
November	35°	0.6 in.	33°	0.8 in.
December	31°	0.9 in.	26°	0.8 in.
Year	46°	21.8 in.	46°	19.3 in.

Plot the precipitation for Spearfish and Oelrichs. Locate these places on the map. What difference in altitude? In precipitation? How would you explain the difference in precipitation?

*196. THE EASTERN MARGIN OF THE ROCKY MOUNTAINS AND THE ADJACENT GREAT PLAINS

The following grouped maps in Colorado: *Pikes Peak, Colorado Springs, Big Springs, Cañon City, Pueblo, Nepesta, Huerfano Park, Walsenburg, and Apishapa.*

In what part of the state is this region? On an outline map, shade this area. What two principal areas appear? What average height has the Plain near the eastern margin of the map? At the western margin of the Plain? What direction does it slope, and at what average rate? How would you describe the dissection of the Plain? What is the general height of the Rocky Mountains in this region? Is their meeting with the Plains straight or indented? What ridges south of Colorado Springs? What is their origin (see Exercise 103)? Trace these ridges. What spur extends into the Plain west of Pueblo?

How high is Pikes Peak? How does its height compare with that of Mount Mitchell? Is Pikes Peak an isolated peak or a part of a range? How high is it above the general altitude of Pikes Peak Range? How high above Colorado Springs? Note the various parks in the Rocky Mountain Range. What important rivers rise in this vicinity? Is the mountain region, in general, densely populated? What is the reason for the group of towns around Cripple Creek?

*197. THE EASTERN BORDER OF THE GREAT BASIN

The following grouped maps: (*Utah*) *Ashley*, *Uinta*, *Salt Lake*, *Toole Valley*, *Sevier Desert*, *Manti*, *Price River*, *East Tavaputs*.

In what part of the state is this region? Shade the area on an outline map. What two physiographic divisions? The mountainous division is in the Colorado Plateau; the Plains division is in the Great Basin. What mountains form the boundary between the Plateau and the Great Basin? What mountains perpendicular to the Wasatch Range? What are the heights of these ranges? One of these ranges is due to an anticlinal folding and the other is a fault scarp (Exercise 105). From their slopes infer the origin of each range. What causes the abundance of lakes in the Uinta Mountains (Exercise 116)? How would you describe the dissection of the Plateau?

What is the average altitude of the Plain? How far, on the average, is it below the Wasatch Mountains? What mountains rise above the Plain? About how high above the Plain? Locate Utah Lake. Do you think it is fresh or salt? Why? What is its outlet? How would you infer the rainfall of the Plain from the drainage? From the land forms?

Lake Bonneville once covered this plain to about the contour of 5200 feet. At this stage how far below the surface was the present site of Salt Lake City? Along the Wasatch Mountains, what contrast between the land above and below the contour of 5200 feet? At the mouths of many of the streams, especially Provo River and Spanish Fork Creek, are old deltas (compare Exer-

cise 127). What delta characteristics have they? Find other examples. North of Stockton a bar was built. How long is it? How high?

Why is irrigation of the eastern border of the Plain comparatively easy? What effect would the use for irrigation of water from the Wasatch Mountains have on the area of Great Salt Lake? Locate on the map the soil section shown in Figure 55. Why are *stony* soils found near the mountains? Why is there *gravelly* loam on the east side of the section and not on the west side? Which soils were deposited in the deeper parts of Lake Bonneville? Where are most of the towns in the Plain located? Why?

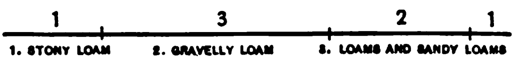


FIG. 55.

Soil Section from the Wasatch Mountains to the Oquirrh Mountains through the Mouth of the American Fork Cañon.

REFERENCES. — "Physiographic Regions," by J. W. Powell, "Physiography of the United States"; Soil Surveys of the Provo, Utah, area (1903) and Goshen, Utah, area (1903).

Plot the temperatures for Salt Lake City. How does your graph compare with New Orleans? What is the monthly range? Is the climate continental or oceanic? Why? Plot the precipitation data. How does the graph compare with that for Bismarck? Which place has the best arrangement of rainfall for crops?

SALT LAKE CITY

	T.	P.	SNOW	R. H.
January	28°	1.3 in.	11.3 in.	75
February	33°	1.4 in.	10.8 in.	70
March	42°	1.9 in.	8.6 in.	58
April	50°	2.1 in.	2.5 in.	48
May	58°	1.9 in.	0.5 in.	47
June	67°	0.7 in.	T.	38
July	76°	0.5 in.	.0 in.	34
August	75°	0.8 in.	.0 in.	35
September . . .	64°	0.8 in.	T.	38
October	52°	1.5 in.	1.0 in.	51
November . . .	40°	1.5 in.	5.8 in.	62
December . . .	33°	1.4 in.	9.7 in.	71
Year	52°	15.8 in.	50.2 in.	52

First killing frost in autumn, October 18.
Last killing frost in spring, April 23.

What is the length of the snow season? How does it compare with that of New England? Nashville? What proportion of the precipitation is snow? How does this snowfall affect the supply of water for the rivers flowing into the Great Basin from the east?

Would you describe the relative humidity as low or high? How does it compare with New England? What effect has this relative humidity on "sensible temperatures"; *e.g.* how would the same temperature, warm or cold, feel in Utah and New England? What effect does this relative humidity in Utah have on the supply of moisture for plants?

What is the length of the season free from frost? How does it compare with New England? Nashville?

AVERAGE HOURLY TEMPERATURES FOR SALT LAKE CITY AND NEW ORLEANS

	SALT LAKE CITY	NEW ORLEANS		SALT LAKE CITY	NEW ORLEANS
1 A.M.	45.8	65.4	1 P.M.	54.7	71.6
2 A.M.	47.8	65.0	2 P.M.	56.3	72.3
3 A.M.	47.0	64.6	3 P.M.	57.2	72.7
4 A.M.	46.3	64.2	4 P.M.	57.9	72.9
5 A.M.	45.8	63.9	5 P.M.	58.1	72.7
6 A.M.	45.2	63.6	6 P.M.	58.0	72.0
7 A.M.	44.7	63.6	7 P.M.	57.2	70.7
8 A.M.	44.7	64.3	8 P.M.	55.8	69.2
9 A.M.	45.1	65.5	9 P.M.	54.1	68.1
10 A.M.	47.0	67.3	10 P.M.	52.0	67.3
11 A.M.	49.8	69.1	11 P.M.	50.6	66.5
Noon	52.5	70.6	Midnight	49.4	65.9

Tampa? Plot the hourly temperatures for Salt Lake City and New Orleans. Which show the greatest range? What, on the average, is the warmest hour at Salt Lake City? At New Orleans? What reason is there for this? Which graphs show the steepest curves? Which graph shows a continental daily range? Which a marine daily range? In this region much trouble is experienced because "alkali" salts are drawn by capillary attraction to the surface of the soil and left there by evaporation. How would the climate explain this process?

*198. THE PLATEAU OF ARIZONA AND THE GRAND CAÑON

The following grouped maps: (*Ariz.*) *St. George*, *Kanab*, *Escalante*, *Henry Mountains*, *Mount Trumbull*, *Kaibab*, *Echo Cliffs*, *Marsh Pass*, *Tusayan*, *San Francisco Mountains*, *Chino*, *Diamond Creek*, *Camp Mohave*, (*Nev.*) *Pioche*, *St. Thomas*.

Locate this region on a general map and shade the area included in the maps. Where does the Colorado River rise? Into what does it flow? What portion of the river is shown on these maps? What length of the Colorado River is shown on these maps? What is its general direction? What is the altitude of the river east of Fremont River (northeast of Mount Holmes)? What is its altitude north of Mount Newberry (near the Nevada-California line, southwestern part of map)? What is the average fall per mile of the river? Do you regard this as above or below the average for most rivers?

Beginning at the northeastern part of the map, trace the cañon. Where does it become very deep? At this point does the land change in elevation? How much? Where does the deep cañon end? Does the land elevation fall here? How much? Locate the portion of the cañon studied in Exercise 80. Of what two parts does it consist here? Is this true of all parts of the cañon?

Make a profile east and west along parallel 36° 30′ and one north and south along the meridian of 112° 45′ (follow method given in Exercise 190).

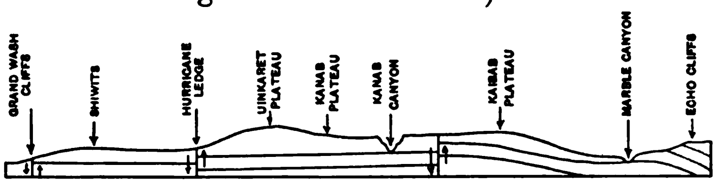


FIG. 56.

Generalized East-west Section across the Grand Cañon Region. (After Dutton.)

From Figure 56 determine the origin of each plateau. Which are bounded by faults? Which by monoclines? What is the origin of the Pink Cliffs (see Figure 57)? The Vermilion Cliffs? How does a north-south section differ from an east-west section in structure? How in its topographic types? Compare the Vermilion and the Pink cliffs with Echo Cliffs; with the Cumberland escarpment; the Niagara escarpment.

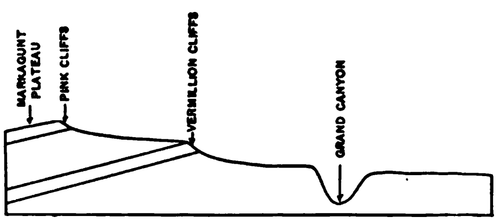


FIG. 57.

Generalized North-south Section across the Grand Cañon District. (After Dutton.)

Note the San Francisco Mountains. How far are they from the cañon? They are mostly rather recent volcanic cones and lava flows. The Uinkaret Mountains

have a similar origin. How do the forms of these mountains suggest their origin? Compare them with the Catskill Mountains (Exercise 83); the Blue Ridge (Exercise 88).

	Yuma, Arizona Altitude, 141 Ft.			Flagstaff, Arizona		
	T	P.	R H.	T.	P.	Snow
Jan.	54°	0.4 in.	50	26.7°	2.00 in.	14.5 in.
Feb.	59°	0.5 in.	49	30.8°	3.28 in.	21.6 in.
Mar.	56°	0.3 in.	46	35.9°	1.81 in.	12.4 in.
April	70°	0.1 in.	39	42.2°	1.63 in.	6.6 in.
May	77°	T.	40	50.7°	1.21 in.	5.3 in.
June	85°	T.	40	59.3°	0.55 in.	0.5 in.
July	92°	0.1 in.	48	65.0°	1.79 in.	.0 in.
Aug.	91°	0.3 in.	52	62.8°	3.30 in.	.0 in.
Sept.	84°	0.1 in.	49	55.5°	2.00 in.	T.
Oct.	73°	0.2 in.	49	44.7°	1.89 in.	0.7 in.
Nov.	62°	0.3 in.	47	34.6°	1.40 in.	12.6 in.
Dec.	56°	0.4 in.	51	28.4°	1.95 in.	7.1 in.
Year	72°	2.7 in.	46	46.7°	22.81 in.	81.3 in.

Mean annual pressure (1904): Yuma, 29.74 in.; Flagstaff, 23.37 in.

Locate Yuma and Flagstaff. How far apart are they? How do they differ in altitude? How much farther north is Flagstaff?

How do their monthly and annual temperatures compare? The snowfall? The pressure? How would you account for difference in annual pressure? How much variation per hundred feet difference in altitude?

Compare the monthly and annual rainfall. Plot the rainfall curve for Yuma. What maxima has it? (This is characteristic of Arizona and New Mexico.) How would you account for the greater rainfall at Flagstaff? Is this distribution of rainfall advantageous for most crops? Why? What two principal factors account for the difference in relative humidity at the two places?

Note the relative humidity at Yuma. What is its highest? Invalids with lung troubles need a mild climate and dry air. Yuma is a winter resort, for such invalids. Why? Why not a summer resort? How does the relative humidity compare with New England? Why is evaporation rapid in the plateau of Arizona and New Mexico? How do native plants protect themselves against this evaporation (see text-books on botany or an encyclopedia)?

*199. THE WESTERN GREAT BASIN AND THE SIERRAS

The following grouped maps: (*Nev.*) *Paradise, Disaster, Long Valley,* (*Cal.*) *Alturas, Modoc Lava Bed, Shasta.*

Review Exercises 106 and 108. How much of the Shasta Quadrangle is covered by the Shasta Special Quadrangle? What is the origin of Mount Shasta? Where in this region are the Warner Mountains?

What is their origin? What is the origin of Long Valley?

Locate this section on a general map and shade the area included in the maps. How long, east and west, is this section? In the eastern part of the section are the "Basin Ranges." Name them. Where have you seen similar ranges? About how high is the Plain? In general how high above the Plain are the ranges? In what direction do the ranges trend? What can you infer as to the rainfall from the land forms? By the drainage? By the dune areas? Why, in general, do the roads skirt the base of the ranges? These ranges are sometimes called "buried ranges" (see the text-books in physical geography or geology). Why?

West of the buried ranges is a lava plateau. How does its topography compare with that of the Plain? How would you describe the dissection of this plateau?

Locate the Sacramento River. Into what does it flow? Trace the divide between this river and the Great Basin drainage. What is its altitude? Is it a sharply defined divide? How does it compare in this respect with the divides on the Coastal Plain? With those in the Appalachian Ridges? In the Cumberland Plateau?

Compare the streams on each side of the Pacific-Great Basin divide; the dissection. Account for the contrasts.

How far is Mount Shasta from the Pacific? The complex mountains in the vicinity of Mount Shasta belong to a group that is sometimes called the Klamath Mountains. What is their average height? What is the average depth of valleys?

Noting the drainage across this area, what can you tell of the rainfall? How would you explain its distribution?

*200. THE SIERRAS IN CALIFORNIA

The following grouped maps: (*Cal.*) *Chico, Bidwell Bar, Downieville, Sierraville, Truckee, Colfax, Smartsville, Marysville,* (*Nev.*) *Reno, Wadsworth, Wabuska, Carson.*

Locate this region on a general map and shade the area included. How far south is it from the area treated in Exercise 199? What is the length of this section? Review Exercises 109 and 140.

Trace the eastern border of the Sierra Nevada Mountains. In what direction is their trend? How high is it above sea level? Above the general altitude of the Great Basin? Where is its slope steepest? Where least steep? How does the Great Basin topography compare with that in the Warner Mountain region? With that in the Utah region? What lakes are there in the Great Basin? How and into what is Lake Tahoe drained? What undrained lakes? What basins not now occupied by water?

How wide is the belt of Sierras here? What is its general height? In which direction do most of the streams flow? In what part is the Pacific-Great Basin divide? What are the principal streams? Which does the topography most resemble, that of the Appalachian Ridge Belt or the Alleghany-Cumberland Plateau? What predominant stream pattern? Where has there been glaciation? Do you think it was of the mountain or the continental type? Give full reasons for your opinion.

Compare the eastern and western margins of the Sierras in height, dissection, steepness. Which is for the most part an escarpment? One of these edges is for the most part a recent fault scarp. Which do you think is the fault scarp? Why? Which direction has the block including the Sierras evidently been tilted? How do you know?

What is the altitude of the Sacramento Valley? How do this valley and its river compare with the same valley and river noted in Exercise 199? How would you describe the surface of the valley? What natural facilities for irrigation in the valley?

Trace the Central Pacific Railroad. What physiographic features does it use? The old California trail followed the Truckee River to the Donner Pass and thence down the American or Bear River to the Sacramento Valley. Where is the highest point on the trail?

How does this pass compare with the Cumberland Gap?

Which division, the Great Basin, the Sierras, or the valley of the Sacramento, offers the best soils? How would you account for the number of towns in the Sierras?

REFERENCES. — The following folios, U.S.G.S., Marysville, Smartsville, Colfax, Truckee.

	Chico, Cal.		Donner, Cal.			Carson City, Nev.		
	T.	P.	T.	P.	Snow	T.	P.	Snow
Jan.	47°	4.5 in.	28°	8.2 in.	79 in.	33°	2.0 in.	8.3 in.
Feb.	50°	3.3 in.	29°	7.0 in.	74 in.	36°	1.6 in.	10.2 in.
Mar.	56°	2.7 in.	31°	8.0 in.	84 in.	41°	1.3 in.	7.5 in.
April	62°	1.8 in.	36°	5.2 in.	55 in.	47°	0.6 in	2.2 in.
May	68°	1.0 in.	43°	2.1 in.	20 in.	54°	0.8 in.	0.4 in.
June	77°	0.4 in.	53°	0.6 in.	2 in.	61°	0.3 in.	T.
July	84°	T.	61°	0.2 in.	0 in.	68°	0.1 in.	0 in.
Aug.	82°	T.	60°	0.5 in.	0 in.	67°	0.3 in.	0 in.
Sept.	75°	0.5 in.	54°	0.2 in.	2 in.	60°	0.3 in.	0.0 in.
Oct.	65°	1.4 in.	44°	2.5 in.	14 in.	50°	0.5 in.	0.9 in.
Nov.	54°	2.6 in.	36°	4.5 in.	35 in.	42°	1.3 in.	1.5 in.
Dec.	48°	4.2 in.	30°	7.9 in.	68 in.	34°	1.7 in.	5.0 in.
Year	64°	22.4 in.	42°	46.9 in.	433 in.	49°	10.8 in.	36.0 in.

First killing frost in autumn: Chico, December 14; Carson City, September 20.

Last killing frost in spring: Chico, March 24; Carson City, May 20.

Locate Chico, Donner (near Donner Lake on the Central Pacific Railroad), and Carson City. In what physiographic divisions are they located? What are their altitudes?

Plot the temperatures for these places. What are the monthly temperature ranges? In what months does the maximum come? The minimum? Account for the differences in temperature between Chico and Donner; between Chico and Carson City; between Donner and Carson City.

Plot the precipitations for these places. Are the graphs parallel? Which are most nearly parallel? When does the maximum precipitation come? The minimum? This arrangement of precipitation is called the "Pacific Type." How would you describe the type? How does this compare with the precipitation of Bismarck, Nashville, and Tampa?

How would you explain the difference in precipitation between Chico and Donner? What percentage falls during the crop-growing season? What are the snow months at Donner? At Carson City? What is the length of the snow season at these places? Give at least two reasons for your answer. What percentage of the total precipitation at these places is snow? What advantage to the people in the Sacramento Valley has the snowfall in the mountains?

The snowshed system of the Southern Pacific Railroad extends from Blue Cañon to Truckee. What is its length? Compare the temperatures of the three regions for wheat growing. For fruit. Why is irrigation desirable in this part of California, which has a

rainfall of over twenty inches? From the frost dates, what region would you think favorable for fruit growing? Much wheat is grown in the Valley of California. What climatic factors favor this crop?

NOTE. — Summit, Cal., near Donner, is the station from which the data for Donner is given. Summit is not shown on the map.

California is a state with many varieties of climate. The section given above is in what part of the state? In what part of the state is the map in Exercise 60 located? Along the alluvial fans are some of the most extensive vineyards of raisin grapes in the country. How does the raisin grape differ from other grapes? It needs a warm climate, sunshine, and a rainless season for drying. How do the following data at Los Angeles fit these requirements?

	Los Angeles				Independence			
	T.	P.	R. H.	Sunshine[1]	T.	P.	R. H.	Sunshine[1]
Winter	55	8.9 in	65	74	43	2.0 in.	41	72
Spring	60	4.3 in.	73	66	56	0.6 in.	27	82
Summer	70	0.1 in.	75	74	76	0.2 in.	20	89
Autumn	65	2.3 in.	70	77	60	0.9 in.	28	85
Year	62	15.6 in.	71	73	59	3.7 in.	29	82

[1] Percentage of possible sunshine.

The grapes are often taken to the "desert" to dry. Independence is located on the western edge of this

"desert." Locate it on a map of the state. How does the sunshine of Independence compare with that of New Orleans? Which has the more cloudy weather? Which the greater relative humidity? What factors in the desert promote raisin making? Are these factors favorable for crops? Which of the two stations, Los Angeles or Independence, have continental climates? How do you know? Which marine? Why?

201. THE NORTHERN CASCADE MOUNTAINS AND THE COLUMBIA PLATEAU

The following grouped maps: (*Wash.*) *Glacier Peak, Stehekin, Methow, Okanogan, Chelan, Chiwankum, Skykomish.*

Shade this area on a general map. In what part of the state is the area located? In what direction from Seattle? How far and in what direction is this area from those shown in Exercises 199 and 200?

On a general map trace the Columbia River. What part of this river is shown in this map? Trace on a general map the Cascade Range. What portion is shown in this map? What is the general altitude of the peaks of this range? What is the general altitude of the Columbia Plateau? What difference in altitude between the two divisions?

Note and locate the glaciers. What is the general lower limit of glaciation? How does this compare

with Mount Shasta? Do you find the same distribution of glaciers as on Mount Shasta? In general, how are the glaciers in this region distributed with respect to the divide? How will the following table for a station in this vicinity explain this distribution? (Explain fully.)

Average Number of Winds from Different Directions at Portland, Ore. (1891–1895)

N.	1498	S.	1835
N.E.	454	S.W.	1083
E.	310	W.	283
S.E.	1033	N.W.	2076

Do you think that this topography is due mainly to glacial or to subaërial erosion? What features are plainly of glacial origin? What features are largely due to subaërial erosion? How does the region compare with the Mount Washington district? With the Gilbert Peak district? With the Mount Mitchell district? Compare the surface of the Columbia Plateau with that of the Cascade Range.

Trace the Stehekin River. Is there any peculiarity? How long is Lake Chelan? What average width? How far, on the average, is it below the uplands? How would you describe the valley sides? How do these compare with those of Cayuga Lake (Exercise 127)? Trace the divide on either side of Lake Chelan. How

far on the average is the divide west of the lake? East of the lake? Is this usual? Why?

What glacial features on either side of Sawtooth Ridge? Find other examples.

T

APPENDIX

Apparatus. — Cross-section paper should have about ten squares to the inch. Blank maps of the United States will be needed in the areal studies.

Ex. 2. — Any device will do that will give a horizontal wire that can be revolved about an axis. A ring stand from the chemical laboratory with a wire fastened to the ring will do fairly well. The Central Scientific Supply Co., 14 Michigan Street, Chicago, will furnish the apparatus for $1.00.

Ex. 3. — Compass and globe can be procured from dealers in apparatus.

Ex. 9. — Goode's Sun Board can be procured from the Central Scientific Supply Co. (see above), price $12.00.

Daily weather maps can be procured on application to the nearest station. Usually half a dozen or more daily maps will be sent to teachers for use in the classroom. It is a good plan to select good type maps and preserve them for reference. In this way a valuable working collection will soon be formed. Blank weather maps (form *DD*) can be ordered from the Weather Bureau for about 20 cents per hundred.

Rocks and minerals may be obtained from the following firms: Foote Mineral Co., 107 North 9th St., Philadelphia, Pa.; Ward's Natural Science Establishment, 16 College Ave., Rochester, N.Y.; Central Scientific Co., 14 Michigan St., Chicago, Ill.

If the teacher is in a glaciated region, usually specimens of most of the rocks called for can be found. The local granite dealer can often supply most of them. It should be remembered that the term "granite" in trade is usually applied to almost any igneous rock. Often the teacher can obtain a good collection by exchanging local material. There are few localities that cannot furnish interesting material.

Charts. — All purchases from the government bureaus should be accompanied by remittances, either in cash or money order. Mississippi River charts are published in two scales: one of one mile to the inch, price 10 cents; and the other of three miles to the inch, price 26 cents. Remittances should be sent to the Mississippi River Commission, St. Louis, Mo.

Coast charts are issued by the U. S. Coast and Geodetic Survey, Washington, D.C., where orders should be sent. This Survey sends free a catalogue of its charts.

Coast Charts. — 314, Kennebec and Sheepscot Rivers (25 cents); 315, Casco Bay (25 cents); (both for reference); *1007, Gulf of Mexico (50 cents); *5300, Santa Rosa Island to Point Buchon (50 cents); *120, New York Bay and Harbor (50 cents); *152, Newfoundland Harbor to Boca Grande Key (50 cents); *5532, San Francisco Entrance (50 cents); *121, Sandy Hook to Barnegat Inlet (50 cents); *110, Cape Cod Bay (50 cents); 123, Absecon Inlet to Cape May (50 cents); 359, Thames River and Harbor of New London (40 cents); *337, Boston Harbor (50 cents); 5100, San Diego to Santa Monica (50 cents); *194, Mississippi River from the Passes to Grand Prairie (50 cents); *195, Mississippi from Grand Prairie to New Orleans (50 cents); *204, Galveston Bay (50 cents); *5500, Pacific Coast from Point Pinos to Bodega Head (50 cents); *469, Key West Harbor (25 cents); 244, Salem Harbor (25 cents).

Charts of the Hydrographic Office, Navy Department, Washington, D.C.

1850, Port Apra, Guam (60 cents); 1802, Funafuti Atoll (60 cents).

Pilot charts of the North Atlantic Ocean, price 10 cents. Often canceled or unused charts will be sent free to schools.

Charts of the Lake Survey, War Department, *No. 2, Lake Ontario, *No. 3, Lake Erie (15 cents each). Remittances should be made by money order payable to the order of U. S. Lake Survey Office, at the Old Custom House, Detroit, Mich., or to the order of U. S. Engineer Office, at Federal Building, Buffalo, N.Y.

"*Tide tables*," price 50 cents, gives much interesting information from stations in different parts of the earth. Data may be found for the Atlantic coast in "Tide Tables for the Atlantic Coast" (15 cents), and for the Pacific coast in "Tide Tables for the Pacific Coast" (10 cents). Order from the U. S. Coast and Geodetic Survey.

Reports of the U. S. Soil Survey are not on sale, but may often be obtained from your congressman. These reports contain much valuable geographic material.

Folios issued by the U. S. Geological Survey are recommended as follows (the price is 25 cents each, except the New York City Folio, which is 50 cents): Absaroka, Wyo.; *Telluride, Col.; *Ellensburg, Wash.; *Fargo, N.D.; Mt. Mitchell, N.C.–Tenn.; Kingston, Tenn.; Pikeville, Tenn.; McMinnville, Tenn.; Marysville, Cal.; Smartsville, Cal.; Colfax, Cal.; Truckee, Cal.; *New York City, N.Y.; Greenville, Tenn.; Holyoke, Mass; (any one of the following will be sufficient for Ex. 194) Edgemont, S.D.–Neb.; Oelrichs, S.D.–Neb.; Newcastle, Wyo.; Sundance, Wyo.

Books. — No extended bibliography has been included in the Manual. As a rule, references are given only to those

books that pertain to the *area* under discussion. Books published by the U. S. Geological Survey are indicated thus: U.S.G.S. Of course, the school library should include the various text-books, especially if the topical method is followed. Reports of the U. S. Geological Survey that are out of print are not included in this list. Climate, Ward, Putnam ($2.00); Physical Geography of New York, Tarr, Macmillan Co. ($3.50); Geographic Influences in American History, Brigham, Ginn & Co. ($1.25); American History and Its Geographic Conditions, Semple, Houghton Mifflin Co. ($3.00); Cumberland Road, Hulbert, A. H. Clark ($2.50); Physiography of the United States, American Book Co. ($1.50), U.S.G.S.; Monograph 41, Drainage Features of the Erie and Ohio Basins, by Frank Leverett ($1.75); Monograph 25, The Glacial Lake Agassiz, by Warren Upham ($1.70); Professional Paper No. 34, The Delavan Lobe of the Lake Michigan Glacier, by Wm. C. Alden (a limited number are for free distribution); Professional Paper No. 40, The Interpretation of Topographic Maps, by R. D. Salisbury and W. A. Atwood, is valuable and will be sent free to teachers.

Topographic Maps Needed in the Text.—Those maps needed for the suggested briefer course are starred (*). A few maps useful for reference are indicated by the word *reference*. They should be ordered from the U. S. Geological Survey, Washington, D.C. Unless otherwise stated, the price is 3 cents per map if 100 or more maps are ordered. For orders for less than 100 maps the price is 5 cents each.

Ala.: Gadsden.

Alaska: *Nome Special.

*Ark.: Marshall.

Ariz.: *Bright Angel, (5 cents) *Mt. Trumbull.

Cal.: *Alturas, Corona, *Cucamonga, *Marysville, *San Luis, *Shasta Special (5 cents), Sierraville, *Temalpais.

Col.: *Telluride, Denver (5 cents).
Conn.: *Hartford, New London.
Fla.: *Arredono, Dunnellon (reference).
Ga.: *Marietta.
Ia.: *Anamosa.
Ill.: Highwood, Peoria.
Kan.: *Caldwell, Abilene.
La.: Bayou Sara, *Donaldsonville, East Delta, *New Orleans, West Delta.
Me.: Bath, *Boothbay.
Md.: Frostburg, *Grantsville, *Pawpaw.
Mass.: Abington, *Boston, *Boston Bay, Holyoke, Plymouth, *Provincetown, *Wellfleet.
Minn.: *St. Paul.
Neb.: *Lexington.
Nev.: *Long Valley.
N.J.: *Atlantic City, *Navesink, *Raritan, Passaic, Sandyhook, Trenton.
N.Y.: Elmira, Harlem, *Islip, *Kaaterskill, *Lockport, *Mt. Marcy, *Niagara Falls, Palmyra, *Rochester, Watkins, Watkins Glen (supplementary).
N.C.: Mt. Mitchell.
N.D.: *Fargo.
Ohio: *Berea, *Mt. Sterling.
Ore.: Crater Lake Special (5 cents).
Pa.: Carnegie (reference), *Chester, Germantown, *Harrisburg, Huntington, *New Bloomfield, Norristown, *Pittsburg, *Waynesburg.
S.D.: *Elk Point.
Tenn.: Briceville, Cumberland Gap (reference), Greenville, Kingston, McMinnville, Nashville (reference), *Pikeville.
Tex.: *Austin.
Utah: Henry Mts., *Gilbert Peak, Manti.

Va.: *Harper's Ferry, *Hampton, *Staunton, Richmond.

Wash.: *Ellensburg.

W.Va.: Buckhannon, Charleston, Guyandot, New Martinsville.

Wis.: *Eagle, *Lancaster, *Portage, *Sun Prairie, *Whitewater.

Wyo.: *Ishawooa.

Mounting Maps. — In the long run, it is economical to mount single sheets. Thin white cotton cloth should be used for the backing. Stretch the cloth on a smooth surface, such as a drawing board or a table top, and thoroughly wet the cloth. A *very* smooth floor will do for the grouped sheets. It should, of course, first be made thoroughly clean. Thoroughly cover the back of the sheet with flour paste, which can usually be obtained from a paper hanger, and lay the sheet smoothly upon the cloth. Carefully press the map to the cloth with a piece of clean cloth or a photograph roller.

Grouped sheets must first be trimmed, leaving the unprinted edges of alternate maps projecting about one fourth of an inch. For example, to trim the nine maps shown in Figure 58, trim 1, 2, and 3 with $\frac{1}{4}$ inch of unprinted paper at the top so that 4, 5, and 6 may be lapped over them. Trim 1 and 2 with $\frac{1}{4}$ inch projecting at the right, so that they may be lapped over on the sides; likewise, trim 4 and 5 with the projection on left sides. In this way, the overlaps are alternate, and the map is not so likely to break along the line of laps. The trimming may be done with shears or with a sharp knife.

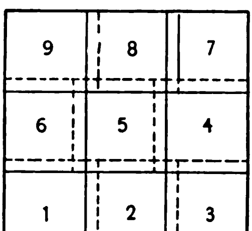


FIG. 58.

Common causes of failure are due to "blisters." The paper in drying separates from the cloth and is soon worn or torn.

This is usually due to air bubbles beneath the paper or cloth, lack of paste, or insufficient or uneven wetting of the cloth. Sometimes the maps crack. This is often due to rough handling or too much paste. If the edges of the maps are not thoroughly pasted and pressed down, they may roll up. Unless one is very expert, the maps should be fitted as trimmed. At least a day is usually required for drying.

Grouped maps should be rolled upon straight, well-seasoned curtain poles. Hanging rings may be screwed into the poles, or cloth loops can be nailed to them. After use, the maps should be carefully rolled and put away, preferably on brackets or shelves.

EXERCISE

Mounted Maps

128. (Minn.) Minneapolis, St. Paul, White Bear, Anoka.

*185. (N.D.) Fargo, Casselton, Tower.

*186. (Kan.) Caldwell, Cheney, Kingman, Anthony.

*187. (N.Y.) Sodus Bay, Oswego, Fulton, Mexico, Syracuse, Baldwinsville, Weedsport, Clyde, Geneva, Auburn, Skaneateles, Tully, Cortland, Moravia, Genoa, Ovid, Watkins, Ithaca, Dryden, Hartford, Apalachin, Oswego, Waverly, Elmira.

*188. Trenton, N.J.-Pa., Navesink, N.J.-N.Y., Passaic, N.J.-N.Y., and Raritan, N.J.

189. (Md.) Green Run, Ocean City, Pittsville, Snow Hill, Princess Anne, Salisbury, Nanticoke, Deal Island, Crapo, Oxford, Bloodsworth Island, Sharps Island, Drum Point, Point Lookout, Prince Frederick, Leonardtown, Piney Point, Montross, Wicomico, Brandywine.

(Va.) Fredericksburg, Mt. Vernon, Harper's Ferry, Warrenton, Spottsylvania, Gordonsville, Luray, Winchester.

EXERCISE

(Va.) Harrisonburg, Staunton, (W. Va.) Franklin, Piedmont, St. George, Beverley, Monterey, Buckhannon, Huntersville, Nicholas, Sutton, Romney, Woodstock.

*190. (N.C.) Yadkinville, Statesville, Hickory, Wilkesboro, Cranberry, Morgantown, Roan Mt., Mt. Mitchell, Saluda, Pisgah, Asheville, (Tenn.) Greenville, Morristown, Mt. Guyot, (N.C.) Cowee, Nahantala, (Tenn.) Knoxville, Maynardsville, Briceville, Loudon, Murphy, Cleveland, Kingston, Wartburg, Standingstone, Pikeville, Chattanooga, Sewanee, McMinnville.

*191. (Pa.) Sunbury, Shamokin, Catawissa, Pine Grove, Lykens, Millersburg, Millerstown, New Bloomfield, Harrisburg, Hummelstown, Lebanon.

192. (Fla.) Williston, Citra, Dunnellon, Ocala, Tsala Apopka, Panasoffkee.

*194. (Conn.) Putnam, Moosup, Stonington, New London, Norwich, Woodstock, Toland, Gilead, Saybrook, Guilford, Middletown, Hartford, Granby, Meriden, New Haven, Winsted, Waterbury, Derby, Bridgeport, Norwalk, Danbury, New Milford, Cornwall, (N.Y.-Conn.) Middlebrook, Clove, Carmel, (N.Y.) Stamford.

195. (S.D.) Rapid, Hermosa, Oelrichs, Edgemont, Harney Peak, Deadwood, (Wyo.) Sundance, Newcastle.

*196. (Col.) Pikes Peak, Colorado Springs, Big Springs, Cañon City, Pueblo, Nepesta, Huerfano Park, Walsenburg, Apishapa.

*197. (Utah) Ashley, Uinta, Salt Lake, Toole Valley, Sevier Desert, Manti, Price River, East Tavaputs.

*198. (Nev.) Pioche, (Ariz.) St. George, Kanab, Escalante, Henry Mts., (Nev.) St. Thomas, (Ariz.) Mt. Trum-

bull, Kaibab, Echo Cliffs, Marsh Pass, Tusayan, San Francisco Mt., Chino, Diamond Creek, Camp Mohave.

*199. (Nev.) Paradise, Disaster, Long Valley.
(Cal.) Alturas, Modoc Lava Bed, Shasta.

*200. (Cal.) Chico, Bidwell Bar, Downieville, Sierraville, Truckee, Colfax, Smartsville, Marysville, (Nev.) Reno, Wadsworth, Wabuska, Carson.

201. (Wash.) Glacier Peak, Stehekin, Methow, Okanogan, Chelan, Chiwankum, Skykomish.

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